Survey of habitat and fish communities in segments of Cherry Creek, a proposed site for the re-introduction of westslope cutthroat trout
by Sean Spence-Patrick Moran

A thesis submitted in partial fulfillment of the requirements for the degree of Master of Science in Biological Sciences
Montana State University

Abstract:
Cherry Creek has been identified as a site for restoration of westslope cutthroat trout. The purpose of this study was to provide pre-restoration baseline data to compare to the future restored westslope cutthroat trout population. These comparisons enabled by the fish community and habitat data will provide a means to judge the relative success of the proposed restoration effort. Three principal reaches were surveyed for physical habitat following R1/R4 stream habitat inventory procedures. These reaches encompassed the area of Cherry Creek between a lower barrier falls and the higher gradient headwaters. Fish population and demographic parameters were estimated from fish gathered during electrofishing depletion estimates. These estimates were performed on three monitoring sections (one in each principal reach) of 402 to 512 m in length during the late summer of 1998 and 1999. Fish population and demographic parameters estimated include: population, density, biomass, length frequency, percent-at-age, length-at-age, annual growth, condition factor, and annual mortality. Macrohabitat results indicated an abundance of high quality habitat, with low gradients of 1.0 to 1.5 %, slow water habitat comprising 20 to 32 % of stream length, mean pool maximum depth of about 1 meter, low sediment, an abundance of woody cover, and favorable water temperatures. Fish population estimates of 835 to 1285 fish/ km, combined biomass estimates of 6.99 to 15.24 g/m2, and combined density estimates of 0.105 to 0.170 fish/m2, for the three sections over the two years indicate a productive system. Length-frequency, and scale and otolith readings indicate a young population, with very few (8 of 247) fish 4 years of age or older. Brook trout comprised a greater percent of the population as the reaches progressed upstream. Mean length-at-age, and back-calculations indicated fast annual growth for the first 2 age classes and much slower growth for ages 2 and above for both species in all sections. Condition factors of about 1.1 for both species in all sections indicated better than average condition. Annual mortality rates were consistently high for both species in all sections over the two years, ranging from 46.0 % (95% CL +/- 39.4 %) to 91.4 %. Habitat and fish correlations indicated that gradient is negatively correlated with rainbow trout distribution and that pool volume is positively correlated with trout growth. Results of this study indicate that lower Cherry Creek has the ability to support a large salmonid population and should the restored westslope cutthroat trout population resemble the present trout community in terms of demographic parameters, the restoration should prove successful.

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Sean Spence-Patrick Moran

This thesis has been read by each member of the thesis committee and has been found to be satisfactory regarding content, English usage, format, citations, bibliographic style, and consistency, and is ready for submission to the College of Graduate Studies.

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ABSTRACT

Cherry Creek has been identified as a site for restoration of westslope cutthroat trout. The purpose of this study was to provide pre-restoration baseline data to compare to the future restored westslope cutthroat trout population. These comparisons enabled by the fish community and habitat data will provide a means to judge the relative success of the proposed restoration effort. Three principal reaches were surveyed for physical habitat following R1/R4 stream habitat inventory procedures. These reaches encompassed the area of Cherry Creek between a lower barrier falls and the higher gradient headwaters. Fish population and demographic parameters were estimated from fish gathered during electrofishing depletion estimates. These estimates were performed on three monitoring sections (one in each principal reach) of 402 to 512 m in length during the late summer of 1998 and 1999. Fish population and demographic parameters estimated include: population, density, biomass, length frequency, percent-at-age, length-at-age, annual growth, condition factor, and annual mortality. Macrohabitat results indicated an abundance of high quality habitat, with low gradients of 1.0 to 1.5 %, slow water habitat comprising 20 to 32 % of stream length, mean pool maximum depth of about 1 meter, low sediment, an abundance of woody cover, and favorable water temperatures. Fish population estimates of 835 to 1285 fish/ km, combined biomass estimates of 6.99 to 15.24 g/m^2, and combined density estimates of 0.105 to 0.170 fish/m^2, for the three sections over the two years indicate a productive system. Length-frequency, and scale and otolith readings indicate a young population, with very few (8 of 247) fish 4 years of age or older. Brook trout comprised a greater percent of the population as the reaches progressed upstream. Mean length-at-age, and back-calculations indicated fast annual growth for the first 2 age classes and much slower growth for ages 2 and above for both species in all sections. Condition factors of about 1.1 for both species in all sections indicated better than average condition. Annual mortality rates were consistently high for both species in all sections over the two years, ranging from 46.0 % (95% CL +/- 39.4 %) to 91.4 %. Habitat and fish correlations indicated that gradient is negatively correlated with rainbow trout distribution and that pool volume is positively correlated with trout growth. Results of this study indicate that lower Cherry Creek has the ability to support a large salmonid population and should the restored westslope cutthroat trout population resemble the present trout community in terms of demographic parameters, the restoration should prove successful.

INTRODUCTION

Westslope cutthroat trout *(Oncorhynchus clarki lewisi)* have been petitioned for listing as a threatened species under the Federal Endangered Species Act (USFWS 2000). Furthermore, westslope cutthroat trout are classified as a State of Montana Class A species, where "limited numbers or limited habitat both in Montana and elsewhere in North America; elimination from Montana would be a significant loss to the gene pool of the species or subspecies" (Hunter 1994).

Habitat degradation, competition, and hybridization with non-native salmonids are the principle reasons why westslope cutthroat trout are now limited to approximately 2.5 percent of their historic range in the upper Missouri River (Shepard et al. 1997). As a result of this decline, the interagency Westslope Cutthroat Trout Steering Committee has set a goal of establishing five areas with at least fifty miles of interconnected habitat in the upper Missouri River basin (MFWP 1999). Cherry Creek has been identified as a project site as part of the Montana Fish, Wildlife and Parks (MFWP) Madison River Drainage Westslope Cutthroat Trout Conservation and Restoration Program (Bramblett 1998).

Unfortunately, this decline, its causes, and the subsequent management strategies employed are not limited to westslope cutthroat trout. The majority of inland salmonid species and subspecies of North America are facing similar circumstances (Behnke 1992). Restoration efforts have been instituted for many threatened species and subspecies (Gresswell 1988, Rinne and Turner 1991, Young 1995), notably: Yellowstone cutthroat trout *O. clarki bouvieri* (Thurow et al. 1988), Colorado River cutthroat trout *O. clarki pleuriticus* (U.S. Department of the Interior 1995), greenback cutthroat trout *O. clarki stomias* (Stuber et al. 1988, Harig et al. 2000), Lahontan cutthroat trout *O. clarki henshawi* (U.S. Fish and Wildlife Service 1995), Gila trout *O. gilae* (U.S. Fish and Wildlife Service 1993), Apache trout *O. apache* (Hanson and David 1989), golden trout *O. mykiss aguabonita* (Pister 1998), and Arctic grayling *Thymallus arcticus* (Kaya 1992, Magee 1998).

The overall management objective of recovery plans, whether they involve trout or other threatened species, is typically delisting or prevention of listing of the species or subspecies in peril (U.S. Fish and Wildlife Service 1995). A threatened or endangered trout species may be considered for delisting, or a candidate species left unlisted, when the restoration plan achieves the goal of increased distribution and abundance. This is in addition to the primary objective of protecting the remaining populations from further decline. Common management strategies employed to meet these goals and objectives include: preservation and rehabilitation of necessary habitat, changes in fishing regulations, establishment of genetically pure and diverse broodstocks, reintroduction of the species or subspecies to enhance its overall numbers and range, and monitoring of the restoration to evaluate success or need for further management (Stuber et al. 1988, Rinne and Turner 1991, U.S. Fish and Wildlife Service 1993, U.S. Fish and Wildlife Service 1995, Young 1995, Pister 1998, Harig et al. 2000).

In the majority of instances, successful restoration of cutthroat trout requires that established, non-native salmonid populations are completely removed and prevented from recolonizing the reintroduction area (Horan et al. 2000). The need for removal and separation from existing non-native trout is indicated by the extensive history of native cutthroat trout being competitively displaced by or becoming hybridized with, non-native trout (Allendorf and Leary 1988, Griffith 1988, Rinne and Turner 1991, Shepard et al. 1997). For cutthroat trout, hybridization with rainbow trout or other subspecies of cutthroat trout has been implicated as the major cause in elimination of numerous populations (Allendorf and Leary 1988, Gresswell 1988, Liknes and Graham 1988, Shepard et al. 1988). The few exceptions to this occur where there is spawning isolation (Liknes and Graham 1988, Thurow et al. 1988), or where suitable habitat and negligible or more regulated fishing pressure, have resulted in cutthroat trout populations that are able to persist with non-natives (Griffith 1988, Thurow et al. 1988, Young 1995). Also, areas of harsh conditions, such as cold, high gradient headwaters where a locally adapted subspecies may have a competitive advantage over an invading non-native, have allowed some cutthroat populations to persist (Gerstung 1988, Griffith 1988, Young 1995, U.S. Fish and Wildlife Service 2000).

It is hardly surprising then, that headwaters constitute the majority of the present distribution of endangered inland trout (Behnke 1992, U.S. Fish and Wildlife Service 2000). These smaller headwater streams also represent the best opportunity for increasing distributions of these species because they are more amenable to the intensive management needed for successful restoration. Paradoxically, the need to institute restoration projects on larger, lower elevation and more productive stream systems is widely recognized (Horan et al. 2000, Hilderbrand and Kershner 2000, Shepard and

Spoon 2001). These larger, more productive, and more physically diverse drainages provide the population numbers needed to ensure survival as well as insuring life history and genetic diversity (Allendorf and Leary 1988, Horan et al. 2000, Hilderbrand and Kershner 2000). Of additional importance is that when entire interconnected sub-basins such as Cherry Creek are used, the restored population is more resilient to local, stochastic events that could cause the extinction of a restored population from a more typical isolated headwater area (Probst et al. 1992, Hilderbrand and Kershner 2000, Horan et al. 2000). The selection of Cherry Creek as a restoration site addresses the desirability for restoration projects to incorporate systems larger and more productive than the headwater streams typically used in restoration projects.

Successful restoration requires the use of piscicides, such as rotenone and antimycin, to ensure the eradication of non-native species because of the unreliability of other means such as electrofishing (Moore et al.1983, U.S. Department of the Interior 1995, Thompson and Rahel 1996). In addition, natural or constructed barriers must be employed to prevent recolonization of restored reaches (Stuber et al. 1988, Rinne and Turner 1991, Pister 1998, Harig et al. 2000). Extensive monitoring over many years to confirm the recovery of the native species, as well as the absence of competitors, is also an essential part of any restoration plan (Rinne and Turner 1991, U.S. Fish and Wildlife Service 1993, U.S. Fish and Wildlife Service 1995, U.S. Department of the Interior 1995, Pister 1998, Harig et al. 2000). The need for these techniques, as well as the economic and political ramifications involved, precludes their use on larger rivers. Cherry Creek therefore represents an ideal compromise between treatable size and size needed to for a large restored population in a diverse area.

Results from more than three decades of restoration are mixed (Rinne and Turner 1991). Instances of success, such as the eradication of an introduced, and potentially catastrophic, population of brook trout from Arnica Creek in Yellowstone National Park (Gresswell 1991) are tempered by many failures (Rinne and Turner 1991, Harig et al. 2000). In fact, reintroduction programs are often expressed as a percentage of the instances where successful (stable and reproducing) populations have been established in relation to the total number of attempts to recover the species (Stuber et al. 1988, Rinne and Turner 1991, U.S. Fish and Wildlife Service 1995, Pister 1998, Harig et al. 2000). The percentages of successful restorations typically range from less than 40 % (Harig et al. 2000), to greater than 65 % (Rinne and Turner 1991). According to Rinne and Turner (1991), most restorations failed due to incomplete kill of the target species or unauthorized reintroduction. Examples of incomplete eradication are widespread and range from problems with electrofishing removal (Moore et al. 1983, Thompson and Rahel 1996, Shepard and Spoon 2000), to the use of unsuitable piscicides (Pister 1998). Pister's summary of the Kern River Golden trout recovery efforts points out another potential obstacle to complete eradication of non-natives that is shared with Cherry Creek. This is the need to apply toxicant to connected marshy areas to ensure eradication of young-of-the-year fish. Barrier structure failure is a common source of failure for many restoration projects, and is usually a result of improper design or materials, or severe hydrologic events (Rinne and Turner 1991, Pister 1998, Harig et al. 2000).

Perhaps most disturbingly, unauthorized reintroduction has been suggested as the reason for finding non-natives in reaches where previous reintroduction efforts were found successful (Rinne and Turner 1991, Harig et al.2000). Regardless of previous success rates, further implementation of practical restoration projects is mandated by the current emphasis on native fish recovery plans.

The pre-restoration data collected in this study will facilitate monitoring and evaluation of the restored westslope cutthroat trout population. By comparing the future restored population to the present community of non-native trout, a more specific evaluation of the degree of success of the restoration effort should be possible. Success of the restoration, and suitability of the site selected, could be evaluated by comparing the restored population's parameters to the capacity of the stream to support salmonids, as indicated by the parameters of the present non-native community. Such comparison would be possible with the demographic parameters of the non-native fish community determined by this study. Such pre-treatment data has generally been lacking in other restoration programs. In one instance where pre-treatment surveys were conducted, their purpose was to judge suitability of the site for reintroduction of Colorado River cutthroat trout (U.S. Department of the Interior 1995). More commonly, pre-treatment surveys were designed to determine distribution and abundance of the invasive, non-native species in order to decide where restoration efforts should be concentrated (Rinne and Turner 1991, U.S. Fish and Wildlife Service 1995, Pister 1998). Extensive before and after comparisons to estimated parameters of the present non-native community will allow for a more thorough evaluation of the restored native fish population, and perhaps may enable development of better recovery standards (Probst and Stefferud 1997).

Since the habitat found in Cherry Creek was judged suitable (Bramblett 1998), the parameters of the restored population such as biomass, density, condition, and growth rates should compare favorably to the baseline data taken on the existing non-native communities. This is in part due to similarity of the habitat requirements listed in the Habitat Suitability Index Models for the present species, rainbow trout (*O. mykiss*) and brook trout (*Salvelinus fontinalis*), and the restored species (westslope cutthroat trout) (U.S. Fish and Wildlife Service 1982a, 1982b, 1982c). Further support for this assumption is found in Platts and McHenry's (1988) summary of density and biomass of various trout assemblages in western streams, where no significant differences were found between densities and biomass in streams that had one trout species (allopatric), versus those that had more than one (sympatric).

The examples of similar densities and biomass for various stream salmonid assemblages suggest that elements of biological control, particularly competition, do not play a major part in determining overall productivity in most systems. Although some instances of non-native species removal have shown evidence of biological control, in the form of interactive segregation and niche shifts (Fausch and White 1981, Griffith 1988), there has been little evidence supporting resultant decreases in biomass due to less efficient resource partitioning (Nilsson 1967, Moore et al. 1983, Fausch 1988). Indeed, some studies showed inconclusive, or contradictory, evidence of niche shift, or displacement (Griffith 1972), or changes in biomass or standing crop (Moore et al. 1983), due to species removal. Ecological release is a common result in systems where a competitor is removed from a sympatric community with a depressed native population (Fausch and White 1981, Shepard and Spoon 2001). Shepard and Spoon (2001) found that higher biomass of the allopatric population versus the sympatric community was temporary, with the final result that the released population biomass levels returned to levels similar to those of the pre-restored sympatric community.

Conversely, the evidence for abiotic control, or physical factors, affecting trout densities and biomass is more convincing. Physical factors influencing density, biomass, and growth rates of trout populations include, but are not limited to: geomorphology (Platts 1979, Lanka et al. 1987); elevation (Lanka et al. 1987, Scarnecchia and Bergersen 1987, Probst and Stefferud 1997); percent suitable substrate (Lanka et al. 1987); gradient (Lanka et al. 1987, Probst and Stefferud 1997, Horan et al. 2000); percentage of undercut banks (Horan et al. 2000); width:depth ratio (Binns and Eiserman 1979, Scarnecchia and Bergersen 1987); flow (Herger et al. 1996); and pool quality (Lewis 1969).

The widespread similarities in demographic parameters such as biomass between sympatric and allopatric salmonid populations validate the use of the non-native, sympatric, salmonid parameters presented in this study for judging the relative success of the future Cherry Creek restoration effort. Comparisons of the community parameters in various sections of Cherry Creek that differ in physical habitat attributes may help elucidate which abiotic (habitat) factors contribute to the observed characteristics of the non-native salmonid community. By describing the existing non-native salmonid community and its relationship to the habitat, this study should provide a framework in which to judge not only the relative success of the future restoration, but may also help to determine if the restored westslope cutthroat trout population differs in its relationship with the physical habitat of lower Cherry Creek.

Study Purpose and Objectives

Purpose

The purpose of this study is to evaluate present salmonid populations and available habitat in three sections of lower Cherry Creek to provide baseline data for comparisons to future restored westslope cutthroat trout, and possibly Arctic grayling, populations. The comparisons can then be used to judge the relative success of the restoration as well as to help determine factors related to the observed characteristics of the restored westslope cutthroat trout population.

Objective 1

Estimate present fish demographic parameters and population characteristics in representative stream sections within lower Cherry Creek. Demographic parameters include population, density, and biomass estimates. Population characteristics include percent-at-age, mean length-at-age, growth rate, condition factor, and mortality estimates.

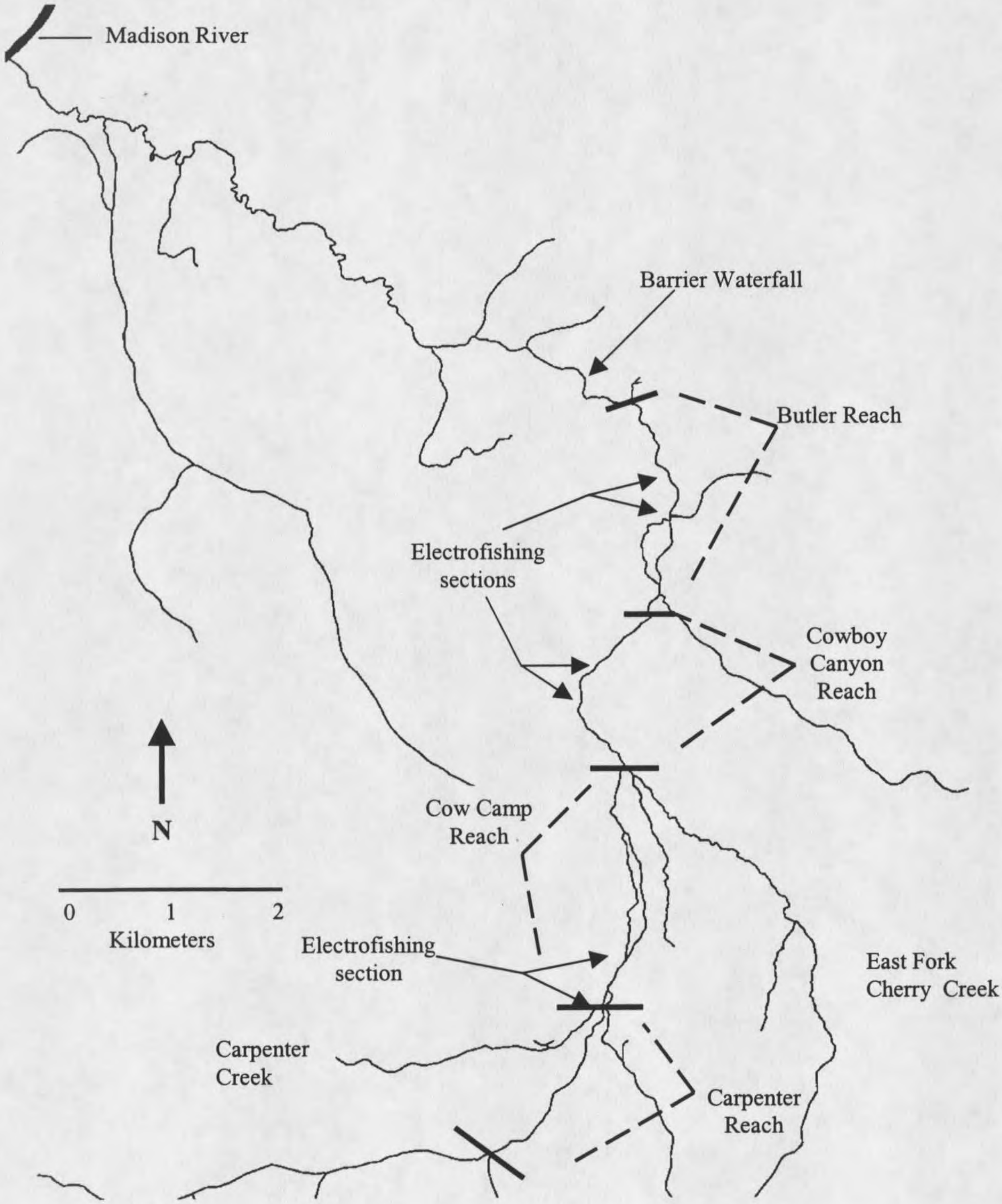
Objective 2

Compare estimated demographic parameters and population characteristics between reaches and species to determine whether significant differences exist and whether measured stream habitat features correlate with estimates of fish demographic parameters.

STUDY AREA

Cherry Creek flows in a northerly direction from the Spanish Peaks to the lower Madison River. From Cherry Lake, and other headwater sources, downstream to the barrier falls, the Cherry Creek drainage includes over 96 kilometers (60 miles) of streams judged to be suitable habitat for westslope cutthroat trout (Bramblett 1998). Several features of the Cherry Creek drainage (Figure 1) make it an ideal site for westslope cutthroat trout restoration. The drainage is blocked to any upstream non-native recolonization by a 7 meter (25 foot) high waterfall located approximately 10.5 kilometers (8 miles) upstream from its confluence with the Madison River. The waterfall may be a result of the geological history of the area, in that a major fault, coincidentally named the Cherry Creek Fault, underlies the area. The fault also delineates a major change in the parent material of the drainage, with limestone outcroppings becoming more common on the south, or upstream side of the fault (S. Custer, Dept. of Earth Sciences, Montana State University, personal communication 2001). The presence of limestone in the drainage may help explain the relatively high productivity of the stream, in terms of numbers of fish, as it is widely recognized that macronutrients dissolved from limestone increase the productivity of aquatic ecosystems (Platts 1979, Scarnecchia and Bergsen 1987). Cherry Creek's headwaters drain pristine National Forest lands, including a portion of the Spanish Peaks Unit of the Lee Metcalf Wilderness Area. The Flying D Ranch-Turner Enterprises Inc owns the lower drainage. This ownership has resulted in a comparatively unimpacted drainage, and simplifies the multi-jurisdictional

Figure 1. Map of lower Cherry Creek from mouth to top of Carpenter reach showing habitat inventory reaches and electrofishing sections.



cooperation required for a project of this scale. A qualitative habitat survey performed on the Flying D Ranch sections of Cherry Creek judged water quality, sediment levels, temperature, spawning and pool habitat, and riparian conditions as suitable for westslope cutthroat trout (Bramblett 1998). Presently, this habitat is inhabited by an abundant community of brook and rainbow trout.

METHODS

Study Reaches

Because the lower gradient areas of Cherry Creek were considered to contain the best habitat of the drainage available for restoration of westslope cutthroat trout and Arctic grayling (Kaya 1992), and because upper reaches were to be sampled by others, the selection of three contrasting reaches was limited to the portion of Cherry Creek between the barrier waterfall and the higher gradient headwaters located above Cow Camp basin. Two of the three principal reaches, Butler and Cow Camp, were chosen based on their lower gradient and abundance of high quality pool habitat. The upper reach (Cow Camp) was lower order, third versus fourth, and had a slightly higher gradient, 1.5 versus 1.0 percent observed gradient, than the Butler reach. The third principal reach (Cowboy Canyon) was chosen as a contrast and to establish the amount of fish that this middle, and sometimes intermittent, reach could support. In addition, a fourth, transitional reach (Carpenter Reach) was surveyed for habitat characteristics so that all lower areas of Cherry Creek were surveyed similarly. Although this reach contained a small amount of lower gradient habitat resembling the Cow Camp reach, it was predominantly comprised of higher gradient habitat more associated with the headwater areas of Cherry Creek. Due to this, and because a majority of the reach was upstream of the study area (from the barrier falls upstream to Cow Camp Basin), the

Carpenter reach did not contain an electrofishing section; and is only included to provide an example of the habitat found upstream of the study area.

Survey reaches were numbered as follows: the Butler reach as reach number 4, Cowboy Canyon as reach number 5, Cow Camp as reach number 6, and finally reach number 7 (Carpenter reach). Reach numbering began at four in order to accommodate future numbering of reaches below the barrier waterfall.

Macrohabitat Parameters

The three principal study reaches for this project were located in the lower portion of the drainage above the barrier falls (Figure 1). The Butler Reach began just upstream of the barrier falls and continued for approximately 2.4 kilometers (1.5 miles) upstream to a barrier diversion dam. A meandering channel ("C type" after Rosgen 1994), deep meander pools, and an abundance of willow (*Salix spp.*) cover characterized this reach. A diversion dam marks the downstream end of the next reach known as Cowboy Canyon. This reach, as its name implies, was more confined, yet was still low gradient (1.2 %). It encompassed approximately 2.8 kilometers (1.7 miles) of stream between the dam and the mouth of East Fork Cherry Creek. Though reported to become intermittent in areas during drier years (C. Francis, former Turner Enterprises employee, personal communication), flows were maintained through this reach during the two years of this study. The third principal reach began at the mouth of the East Fork and continued 4.2 kilometers (2.6 miles) upstream to the mouth of Carpenter Creek. Here the valley bottom opened up again into an area known as "Cow Camp". The stream here resembled a slightly smaller and higher gradient version of the Butler Reach. The Cow Camp section also had numerous beaver (*Castor canadensis*) dammed backwater areas off the main channel.

To quantify and qualify stream habitat, macrohabitat measurements were taken in each reach in accordance with USDA Forest Service's R1/R4 (Northern/Intermountain Regions) fish habitat inventory procedures (Overton et al. 1997). Measurements included: habitat type (pool type or fast-water type), length of habitat unit (HU), HU width, HU average depth, maximum and crest depths (pool HU), number and average maximum depth of pocket pools (fast water HU), percent surface fines and substrate composition (both visually estimated and measured by Wolman (1954) pebble counts and surface fines grate measurements), bank stability (percent estimate), number of large woody debris pieces (including singles, aggregates and root wads), and dominant and subdominant riparian vegetation types. Measurements of length and width were performed using a tenth-of-meter measuring tape or hip chain, while depths were measured using a tenth-of-meter stadia rod.

Percent channel gradient and water temperature measurements were also taken during surveys. Percent gradient was estimated by dividing stadia rod-measured, vertical rise by hip-chain horizontal distance measurements (tenth-of-meters). Photographs were taken and comments were recorded for unusual features, reach breaks, etc. As recommended by Overton et al. (1997), the habitat inventory was performed at base flows during mid-summer to enable proper habitat type identification and future comparisons.

Habitat data was entered into FBASE (USDA Forest Service 1998), a stream habitat data base program, for analysis. This software generated reports that analyzed habitat parameters by reach, such as habitat area (total or mean for the survey reach), volume, mean maximum pool depth, etc. (Wollrab 1998). Habitat measurements were archived on disk and are available through the Ecology Department, 304 Lewis Hall.

This habitat inventory procedure used can be performed at various levels of intensity according to habitat parameters recorded. For this study habitat was surveyed at inventory level II (Overton et al. 1997). This level includes the basic habitat measurements of level I such as habitat length, width, average and maximum depths, etc., and includes further macrohabitat measurements such as: substrate composition, side channel measurements, riparian vegetation types, and large woody debris (LWD) counts. Level II differs from the most intense level of inventory, level III, by not including measurements of bank lengths and LWD dimensions. The level II method was employed primarily because the LWD measurements required for the level III method are more applicable to systems where willow is not the dominant source of LWD (Overton et al. 1997).

Fish Demographic Parameters

Population Estimates

Population estimates were conducted on monitoring sections within each of the three principal reaches in late summer, August 24-28, 1998 and 1999, except for the Butler reach for 1999 which, due to scheduling with Turner Enterprises, was delayed until September 17, 1999. Locations and lengths of each monitoring section were chosen to encompass representative habitat and their approximate frequencies for each respective reach. Estimates were conducted within block-netted monitoring sections of at least 400 m in length, from 402.6 m (Cow Camp), to 492.6 m (Butler), to 512.3 m (Cowboy Canyon). Locations of the sections were confirmed with GPS measurements: 45^{0} 33’55” N by 111^{0} 26’66” W for the bottom end and 45^{0} 33’43” N by 111^{0} 26’61” W for the top end of the Butler section, 45^{0} 32’66” N by 111^{0} 27’28” W and 45^{0} 32’46” N by 111^{0} 27’28” W for the top and bottom of the Cowboy Canyon section, and 45^{0} 30’55” N by 111^{0} 26’98” W and 45^{0} 30’38” N by 111^{0} 27’02” W for the top and bottom ends of the Cow Camp section. Sections varied in length to encompass representative habitat units, and to avoid having electrofishing section boundaries occurring in the middle of habitat units. Length of the sections also helped ensure that extrapolations of the estimates to a longer common unit of length (km) were more accurate than would have been the case if shorter sections were used.

Fish were captured using mobile electrofishing. The electrofishing setup consisted of a gas-powered generator that supplied electricity through a “Leach Box” rectifier (Dr. Harvey Leach, Department of Electrical Engineering, Montana State University) set for an output of 300-400 volts of direct current (DC). This current was applied through the use of a mobile anode; the cathode was attached to an 11-foot-long Coleman "Crawdad" boat that carried the generator, rectifier and a large tub for holding fish. This setup provided the power necessary to sample the larger volume pools found in the Butler reach. Although cumbersome in smaller, upstream sections, this equipment enabled more efficient depletions due to the power provided, the ability to shock continuously for multiple hours, and the range and versatility of a mobile anode. Additionally, because large numbers of fish were caught, the ability to transport these captured fish in a large tub located in the boat meant that for more time could be spent electrofishing, instead of shuttling captured fish to holding pens. Estimates were obtained using a two, or three-pass depletion technique (Zippin 1958, Seber and Le Cren 1967). Field assessments of overall efficiency (capture probabilities greater than 70 %) resulted in all but the Butler section in 1999 conducted as two-pass depletion estimates.

Program Micro-Fish (Van Deventer and Platts 1985) was used to provide population estimates, capture probabilities, and their standard errors. The assumption of geographic closure of the sampled population was met by the use of block nets. Equal effort expended on each pass, and the omission of estimates for young-of-the-year size fish helped to meet the assumptions of equal effort and capture probabilities (Seber and Le Cren 1967, White et al. 1982). As will be seen in the results, population estimates excluded age-0 size fish. This is because capture of young-of-the-year fish in stream electrofishing is generally very inefficient (Lagler 1956, Raleigh and Short 1981, Riley and Fausch 1992, Reynolds 1996). Because the section length varied, population estimates were also expressed as number of fish per km. Calibrating these estimates to a common unit of length enabled an easier comparison with other studies.

Density and Biomass Estimates

Density estimates (number of fish per m^2) were obtained by dividing population estimates for each species, section, and year by the total surface area of the associated section. Surface area was determined by summing the surface areas for all individual habitat units in the respective shocking section.

Biomass estimates (grams per m^2) were estimated by calculating average weights for each species, section, and year, multiplying these values by the respective population estimates, and dividing the resulting products by the total surface area of the respective section. Lengths and weights of fish were measured using a tenths-of-foot measuring board and a tenths-of-pound spring scale; units were later converted to metric (millimeters and grams). Each species' contribution to combined biomass was also recorded as percent of total biomass.

Values of fish or grams per m^2 enable direct comparison to like units used by Platts and McHenry (1988), as well as to other studies where like units were used (Horan et al. 2000, Hilderbrand and Kershner 2000, Shepard and Spoon 2001). Both density and biomass estimates excluded young-of-the-year fish because they were not well represented in the population estimates due to limited sampling efficiency for this size class (Riley and Fausch 1992, Reynolds 1996).

Length-Frequency Distributions

Length-frequency distributions were plotted for each species in each section by year, using a 25.4 mm (1 inch) size interval. Length-frequency histograms were used to infer age structure and mortality. Peaks in histograms were assumed to represent the most common length for a particular age in a population. Analysis of relative strength of each year class was limited to age 1 and older fish because efficiency of capture for young-of-the-year fish was very low (Lagler 1956, Raleigh and Short 1981, Reynolds 1996). Although age-0 fish were under-represented in the length-frequency histograms, the capture of some age-0 sized-fish in most sections enabled me to approximate their length distributions. Ages inferred from length-frequency distributions were also compared with ages assigned from scale and otolith readings (Mackay et al. 1990).

Fish Population Characteristics

Age

While age structure was determined by investigating length-frequency distributions, ages of individual fish were assigned using scales. Scales were collected from a subset of fish of representative lengths during the depletion estimates. The large numbers of fish precluded the aging of each individual fish; accordingly, scales were taken from approximately 10 fish of representative size classes for each species in each section to facilitate construction of an age-length key, described below (Devries and Frie 1996). Scales were scraped from the sides of the fish in an area just posterior to the dorsal fin and just above the lateral line (Mackay et al. 1990). The scales were then placed in sample envelopes on which pertinent information was recorded such as, species, length, weight, section, and date. Scale samples were then pressed into acetate sheets to facilitate reading (Wayne Black, Montana Fish, Wildlife and Parks). Unfortunately, many of the scale samples from many of the older, longer fish were comprised of only regenerated scales that could not be aged.

Otoliths were removed from some of the longer size-classes of fish during the second season for scale verification purposes. By comparing the age of fish determined by scale readings, to the otolith readings from the same fish, evaluation of the accuracy of scale readings is possible (Mackay et al. 1990 and Devries and Frie 1996). Otoliths were removed from fish by cutting away the dorsal portion of the head to reveal the brain case, after which the otoliths were carefully extracted and placed into envelopes labeled as described above for scales. Otoliths were mounted on slides and ground to their center axis to facilitate accurate readings. The prepared otoliths were then back-lighted under a dissecting microscope and the darker annuli were counted and recorded (Brothers 1987).

First year annuli are often missing in inter-mountain salmonid populations, particularly slower growing ones (Lentsch and Griffith 1987). Comparisons of scale readings to length-frequency distributions, back-calculated mean length-at-age, and otoliths demonstrated that missing annuli were not present for fish sampled in this study. A smaller number of otoliths were read for verification of ages determined from scales. Otoliths were needed for verification because scales become less reliable for aging trout over three years in age. Otoliths provided verification for older fish as well as for aging brook trout, which with their much smaller scales with crowded annuli (growth rings), can be difficult to age from scale readings alone (Mackay et al. 1990, Devries and Frie 1996). Ages interpreted from scales and otoliths were verified by having another person experienced with scale and otolith-aging techniques review my results.

Percent-at-Age and Mean Length-at-Age

Calculating the percent-at-age and mean length-at-age of captured fish necessitated estimating ages for all size classes of fish captured. After determining ages for a subset of fish within various size classes, ages could then be assigned to all fish to determine percent-at-age and mean length-at-age (Devries and Frie 1996). The construction of such an age-length key allows for assigning ages to un-aged fish in the same size class. Of particular importance is that size class subsets that have more than one age are used to assigned ages according to the ratio of the subset of aged fish in that size class. However, due to some scale samples being comprised of regenerated scales, many of the sample sizes used for assigning age ratios for some size classes were smaller (less than five) than anticipated.

Due to the inefficiencies of capture for the age-0 size-class of fish, percent-at-age values were limited to age-1 and older fish. Although this omission failed to describe the contribution of age-0 fish to the community, it still allowed for comparisons of the relative contributions of the older ages to the population. In sections where age-0 sized fish were captured, mean length-at-age values were calculated for all ages.

Annual Growth Estimates

Annual growth increments were estimated through back-calculation for collected scales. In addition, annual growth increments were also determined from differences in mean length-at-age of fish captured from consecutive age classes over the two years. Because this latter method depended on differences in mean lengths-at-age of captured fish over consecutive years, it only provided one year of annual growth estimates. Comparisons between the two methods helped in elucidating possible biases in the back-calculated estimates (Devries and Frie 1996). Back-calculation was performed with scales, while otoliths were used as a means of age verification.

Although Weisberg back-calculation analysis is generally preferred, it requires larger sample sizes and samples from multiple years, which were not available in this study; therefore, the less rigorous Fraser-Lee method was employed (Devries and Frie 1996). Under this method the distance of verified scale annuli from the scale's focus were measured along with the distance of the scale's margin from the focus. Fish lengths at previous annuli were estimated according to the Fraser-Lee formula:

$$Li = \frac{Lc - a}{Sc} Si + a$$

where

$$\frac{Lc - a}{Sc} =$$

the slope of a two-point regression line to estimate Li, a = intercept parameter and Li, Lc,Sc and Si are defined as:

Li = back-calculated length of the fish when the ith increment was formed,

Lc = length at capture,

Sc = radius of hard part at capture, and

Si = radius of the hard part at the ith increment.

The resultant back-calculated lengths-at-age were averaged for each age class. Average annual growth was estimated by subtracting back-calculated average lengths at two age classes (Carlander 1969, Mackay et al. 1990, Devries and Frie 1996). For example, growth increments between back-calculated mean length-at-age 1 and back-calculated mean length-at-age 2 was considered age 1 growth (Carlander 1969). Because there were no previous means lengths-at-annuli to subtract, and use of the intercept parameter was problematic due to its dependant nature on regressions of various power, annual growth increments for age-0 fish were not included in the back-calculated estimates. However, using differences between mean lengths-at-age data for fish of consecutive age classes over consecutive years did allow me to approximate annual growth for some age-0 fish. For example, although under-represented, an estimate of mean length-at-age 0 was obtained for some species in some sections in 1998. When this length was subtracted from mean length-at-age estimates for age-1 fish of the same species and section in 1999, an approximation of annual growth for age-0 fish was obtained.

The back-calculated mean lengths-at-age represented lengths at time of annulus formation. Consequently, these values were smaller than mean lengths-at-age values reported for fish captured later in the season. Because annuli were formed in the period immediately prior to the growing season, differences between the two techniques for estimating mean lengths-at-age were a result of growth since annulus formation (Devries and Frie 1996). Additionally, reported back-calculated increments for age classes not followed by an additional age (annuli) were pessimistic as the back-calculated length in these instances represents the distance between last annuli and scale margin and was therefore not representative of an entire years' growth (Carlander 1969).

Condition Factor Estimates

Fulton's condition factor K (Devries and Frie 1996), was calculated for all fish; however, due to the inaccuracy of spring scale readings, only fish 100 mm or longer were used in comparisons for differences in K. The scale inaccuracy was limited to small fish and their associated small weights. This resulted in the small, less than 100 mm long, fish having weights and K values biased high. The use of K values for fish greater than 100 mm in length, typically age 1 and above, enabled better comparisons to be made between species, sections, years, and with other studies where K was used.

Fulton condition factor K, was calculated for each fish following the formula:

$$K = (W/L^3) * 100,000$$

Where W was weight in grams, and L was total length in millimeters. The resultant product is an index of the overall condition of the fish. Values for fish of average condition are typically around 1.0, with values less than this indicating poor condition fish and values much over 1.0 suggesting fish of better than average condition (Carlander 1969, Anderson and Neumann 1996).

Mortality Estimates

Mortality was estimated by establishing age composition of the sampled populations. Estimation of populations and mean lengths-at-age enabled calculation of annual survival for the three monitoring sections. Mortality, the inverse of survival, was estimated separately for each species, section, and year. With the few age classes present, and the collection of only two years' of data, annual survival was calculated using the simplified formula based on coded age after Robson and Chapman (1961). In this method annual survival (S) is estimated by the following formula:

$$S = \frac{T}{n + T - 1}$$

Where n is the total number of fish, beginning with the first age class accurately estimated, and T is determined from the summation of coded age totals and their respective coefficients. The 95% confidence interval, assuming normal distribution of error was calculated by doubling the square root of the estimate of variance (s). Variance was calculated using the formula:

$$s = \frac{T}{n+T-1}\left(\frac{T}{n+T-1} - \frac{T-1}{n+T-2}\right)$$

Statistical Analysis

Comparisons of parameter means were accomplished using one-way ANOVA from the computer program Minitab (1998). Data analyzed were tested for normality by referring to histograms and normality plots of residuals. Comparisons of means of fish demographic parameter estimates such as, population per common unit length, density, and biomass required the use of the two-year's estimates as replicates. In these instances, the associated low degree of freedom (2) meant that only large differences were found significant. Comparisons of fish population characteristics such as, mean length-at-age, annual growth, and condition factor were obtained from the means of many individual fish measurements and as a result were much more robust.

Tukey's pairwise comparison procedure was used in the single factor one-way ANOVA analysis. In a few instances, analysis of only two population means was performed using a two-sample T-test. A significance level of $\alpha = 0.05$ was used for all tests.

Stepwise regression was used to determine which predictors (habitat parameters) best described the response variable (fish population characteristics and demographic parameters). After the best subset of predictors was chosen, each correlation was obtained through the use of a single, simple linear regression. Of the correlations found to be significant ($\alpha = 0.05$), percent variability explained (R-squared values) was recorded. As with the ANOVA analysis, regressions were performed using the statistical software Minitab. Simple linear regressions were also used for correlating length-scale relationships.

RESULTS

Macrohabitat Parameters

Habitat Summary

F-Base summary reports are presented in Appendix A; however, a brief review of the habitat inventory results is summarized below (Tables 1 and 2). As the reaches progress upstream, and Cherry Creek becomes smaller, some expected trends become evident. Slow-water (pool) habitat types consistently decrease in both mean maximum depth, mean width, and mean length. Mean maximum depth for pools decreases from 1.04 m in Reach 4 (Butler) to depths of 0.95 m and 0.94 m in Reach 5 (Cowboy Canyon) and Reach 6 (Cow Camp), respectively. Mean channel width also decreases throughout the reaches, from 7.9 m in the Butler reach (reach 4), to 7.2 and 6.8 m for the respective upstream reaches. Other trends evident, except for a slight departure in the Cow Camp reach (reach 6), is that the characteristic percent of slow water habitat type by length, i.e. (pool:fast-water ratio) decreases progressively in an upstream direction, from 32.4 % (approximately 1:3) in the Butler reach, to 19.8 % (approximately 1:5), 23.4 % (approximately 1:4) and 12.1 % (approximately 1:8) for the Cowboy Canyon, Cow Camp, and Carpenter reaches respectively (Table 1 and Figure 2). The much lower value for the Carpenter reach is indicative of its lower habitat potential and confirms that the three principal reaches represent the majority of the quality habitat found in lower Cherry Creek. Cow Camp's departure from this trend suggests that this reach is second only to the Butler reach in terms of providing quality habitat in the form of greater amount of pool habitat.

Table 1. Summary of main channel habitat dimensions (m), by reach and habitat class.

Reach: 4 (Butler) Type: C

Habitat Class	Habitat Length Total	Habitat Length Mean	Percent	Mean Width	Habitat Depth Mean	Habitat Depth Max	Width: Depth
Riffle	1,000.2	38.5	42.4	8.4	0.24		37.5
Run	594.6	37.2	25.2	7.2	0.33		22.4
Pool	762.8	21.2	32.4	7.7	0.43	1.07	18.4
Totals	2,357.6	30.2		7.9	0.32		27.5

Reach: 5 (Cowboy Canyon) Type: C

Habitat Class	Habitat Length Total	Habitat Length Mean	Percent	Mean Width	Habitat Depth Mean	Habitat Depth Max	Width: Depth
Riffle	1,525.0	35.5	55.1	7.0	0.20		37.2
Run	695.6	30.2	25.1	7.8	0.25		32.5
Pool	546.8	16.1	19.8	6.8	0.38	0.95	18.5
Totals	2,767.4	27.7		7.2	0.25		32.3

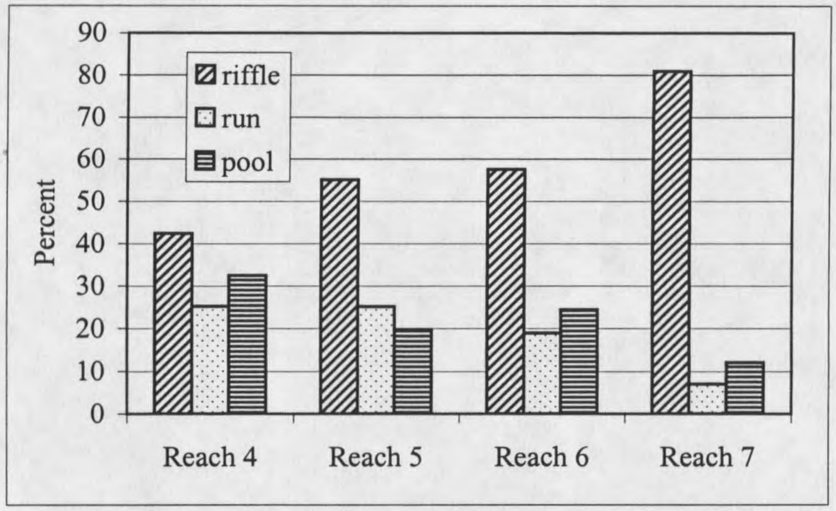
Reach: 6 (Cow Camp) Type: C

Habitat Class	Habitat Length Total	Habitat Length Mean	Percent	Mean Width	Habitat Depth Mean	Habitat Depth Max	Width: Depth
Riffle	2,426.0	39.8	57.6	7.1	0.21		35.5
Run	796.4	22.8	19.0	6.1	0.28		22.2
Pool	986.3	15.9	23.4	6.5	0.37	0.94	18.1
Totals	4,208.7	26.8		6.8	0.26		29.0

Reach: 7 (Carpenter) Type: B

Habitat Class	Habitat Length Total	Habitat Length Mean	Percent	Mean Width	Habitat Depth Mean	Habitat Depth Max	Width: Depth
Riffle	3,003.1	75.7	80.9	6.3	0.18		37.3
Run	259.8	20.6	7.0	4.9	0.24		21.0
Pool	449.5	12.5	12.1	6.0	0.34	0.88	19.1
Totals	3,712.4	41.2		6.2	0.20		34.0

Figure 2. Habitat Class, as percent of total, for the four reaches surveyed.



Other habitat characteristics such as percent gradient, pool volume, percent fines, and numbers of large woody debris for the reaches are presented in Table 2. Percent fines refers to percent of substrate composed of material less than 2 mm in diameter. LWD (large woody debris) refers to dead wood found within the bankfull channel that is at least 3 m in length and .1 m in diameter (singles and aggregate pieces). Root wads are dead root masses not included in single or aggregate counts. Of particular interest are observed gradient and calculated mean pool residual volume. The trend of a gradual increase in observed gradient for the upstream reaches is shown by the measurements of 1.0 % gradient in Reach 4, to 1.2 % (reach 5), 1.5 % (reach 6), and 2.0 % (reach 7) for the progressively upstream reaches. Mean pool residual volume decreases markedly from a high of 114.0 m^3 in the lowermost (Butler) reach to 72.8, 68.8, and 58.5 m^3 for reaches 5, 6, and 7 respectively.

Table 2. Selected macrohabitat parameters by reach. Percent fines refers to percent of substrate comprised of material less than 2 mm in diameter. LWD (large woody debris) refers to deadwood material found within the bankfull channel.

Reach	% Gradient	Pool Volume	% Fines	LWD Number per 100 m Singles	Aggregates	Root Wads
Butler	1.0	114.0 m^3	14.2	0.9	0.9	4.4
Cowboy Canyon	1.2	72.8 m^3	12.9	2.7	2.3	1.2
Cow Camp	1.5	68.8 m^3	8.7	1.4	3.9	3.8
Carpenter	2.0	58.5 m^3	4.2	2.6	3.2	1.7

Fish Demographic Parameters

Population Estimates

Due to the inefficiency of capture of young-of-the-year size classes, population estimates are for age-1 and larger sized fish. For this reason, age-0 size fish were excluded (except for mean length-at-age) from estimates of further demographic parameters and population characteristics.

Comparisons of the population estimates between reaches, species, and years illustrate some common trends. First, total fish per km were relatively consistent across sections and years. Second, the proportion of brook trout increased in the upstream sections. Total population estimates reflect a relatively high number of fish in all three sections for both years (Tables 3 and 4). Combined numbers ranged from 456 to 531 total trout in the three sections in 1998, and 428 to 632 in 1999. Expressed as numbers of fish per km (Figure 3), these three sections supported from 927 to 1,190 brook and rainbow trout combined in 1998, and 835 to 1,285 in 1999. The difference in estimates between the two year's estimates for the Butler section stands out as an anomaly; possible reasons for this will be examined further in the discussion.

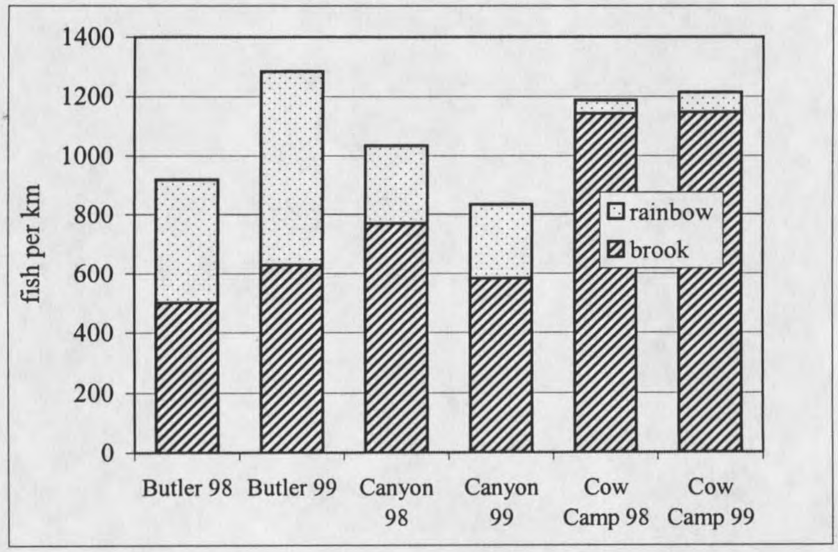
Table 3. Depletion population estimates for the three monitoring sections in 1998.

			1998			
Section	Species	1st Pass	2nd Pass	Estimate	SE	Cap.Prob.
Butler	Brook	174	52	246	8.6	0.71
	Rainbow	149	42	206	7.2	0.73
	Combined	323	95	456	11.78	0.71
Cowboy Canyon	Brook	344	44	394	3.25	0.87
	Rainbow	120	15	136	1.64	0.89
	Combined	464	59	531	3.75	0.88
Cow Camp	Brook	377	69	460	5.59	0.82
	Rainbow	16	2	18	0.52	0.90
	Combined	393	71	479	5.71	0.82

Table 4. Depletion population estimates for the three monitoring sections in 1999.

			1999			
Section	Species	1st Pass	2nd/3rd Pass	Estimate	SE	Cap.Prob.
Butler	Brook	227	60/ 17	309	2.99	0.74
	Rainbow	217	71/ 24	323	4.71	0.67
	Combined	444	131/ 41	632	5.41	0.70
Cowboy Canyon	Brook	272	25	299	1.85	0.91
	Rainbow	117	11	128	1.05	0.92
	Combined	389	36	428	2.24	0.91
Cow Camp	Brook	392	60	462	4.43	0.85
	Rainbow	24	3	27	0.64	0.90
	Combined	416	63	489	4.45	0.85

Figure 3. Combined (brook and rainbow trout) population estimates per km, for section and year.

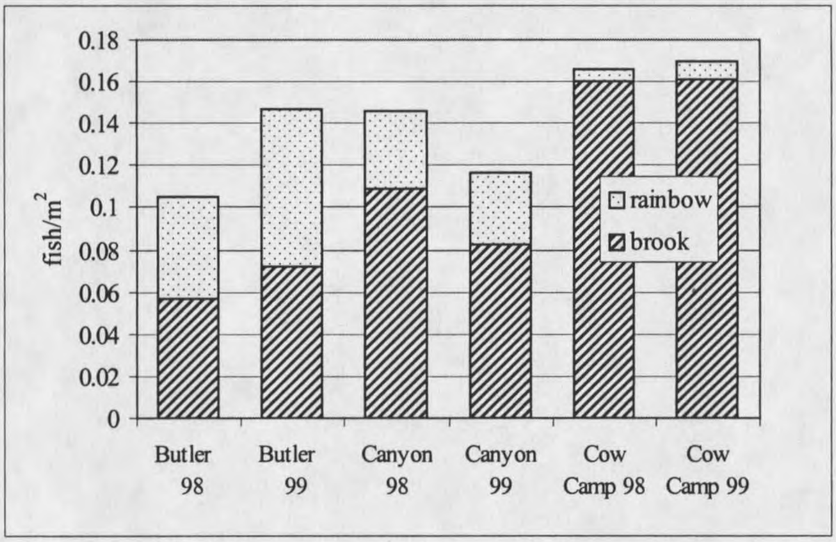


One-way ANOVA comparisons of number of fish for each species per km between the sections, when averaged over the two years, showed numerous significant differences. The low number of rainbow trout in the Cow Camp section were found to be significantly less than all but the number of rainbow trout in the Cowboy Canyon section. Similarly, the consistently high number of brook trout in the Cow Camp section were significantly higher than the two year average for numbers of trout of each species in the other sections. Brook trout were significantly more numerous than rainbow trout in the Cowboy Canyon section. Although the contribution of each species to the total number of fish differed among the three sections, when numbers of each species in each reach were combined and compared, no significant differences were found.

Density Estimates

Overall, the combined estimates and the percents of total density were similar across the two years (Figure 4 and Appendix B). As was the case with the population estimates, the major exception to this trend is found in the Butler section. Combined density estimates ranged from 0.105 to 0.166 fish per m^2 (10.5 to 16.6 fish per 100 m^2) for the three sections in 1998, and 0.117 to 0.170 fish per m^2 (11.7 to 17.0 fish per 100 m^2) in 1999.

Figure 4. Estimated densities of brook and rainbow trout in the three study sections in 1998 and 1999, units are fish per m^2.

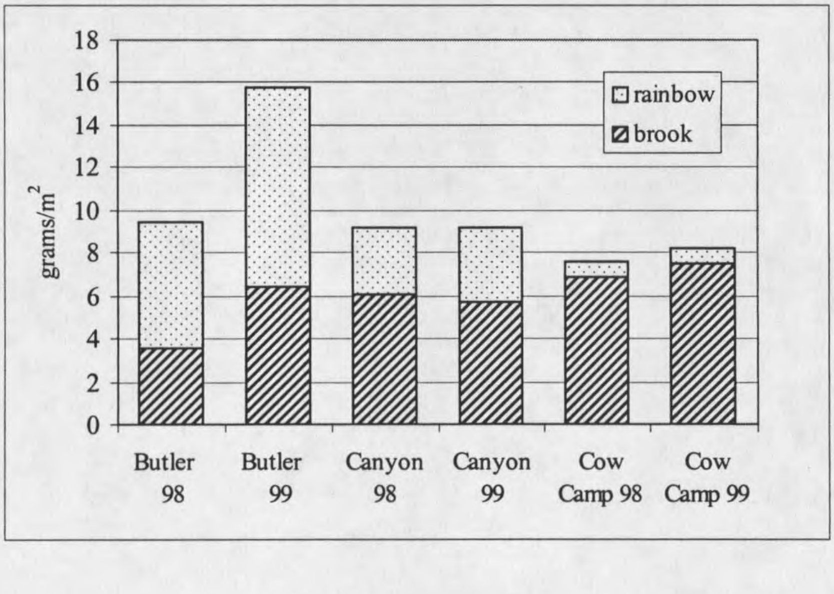


When estimates of density were averaged over the two years and compared using ANOVA, only differences in density between sections for each species were found to be significant. For example, the two-year average for density of brook trout in the Cow Camp section was significantly higher than densities of brook trout in the other two sections. Similarly, the density of rainbow trout in the Cow Camp section was significantly lower than the two-year average density of rainbow trout in the other two sections. As in the population estimates, when the estimates for combined density for each section were compared, no significant differences were found.

Biomass Estimates

Combined biomass, and percent of total biomass were fairly similar (within approximately 25% of each other) for each section across the two years (Figure 5 and Appendix B). The one exception to this pattern was the large increase in biomass from 1998 to 1999 in the Butler section. Revised biomass estimates for brook and rainbow trout combined ranged from 6.99 to 9.39 grams per m^2 for the three sections in 1998, and 8.10 to 15.24 grams per m^2 in 1999.

Figure 5. Estimated biomass of brook trout and rainbow trout in the three sections in 1998 and 1999, units are grams per m^2.



When estimates of biomass were averaged over the two years and compared, only the largest differences between each species were found to be significant. In this case, only the differences between the low average estimates for rainbow trout in the Cow Camp section and the higher average estimates of the Butler rainbow, Cowboy Canyon brook, and Cow Camp brook trout biomass averages, were significant. As in the population and density estimates, when the two-year average for combined biomass estimates for each section were compared, no significant differences were found.

Length-Frequency Distributions

Peaks in length-frequency histograms represent the most common length for respective age classes. For example, the second peak for brook trout (Figures 6 and 7) depicts the most common lengths at age 1. Although under represented in their frequency, the first peaks of the length-frequency histograms indicated that age-0 brook trout ranged from approximately 50 to 100 mm (2 to 4 inches) in all three sections for the two years (Figures 6 and 7). Age-0 rainbow trout were even less abundant, but when depicted in the histograms, ranged from approximately 50 to 75 mm (2 to 3 inches). The next peak in the histograms represents the lengths at age 1, which ranged from approximately 100 to 190 mm (4 to 7.5 inches) for brook trout for the three sections in 1998 and 1999. As with all of the histogram comparisons, the larger of these values were found for the brook trout from the Butler section in 1999 (Figure 7), which due to its later sampling date, represents four additional weeks of growth. The more complete distributions of rainbow trout occurred in the Butler and Cowboy Canyon sections. For

Figure 6. Length-frequency histograms for the three sections, 1998.

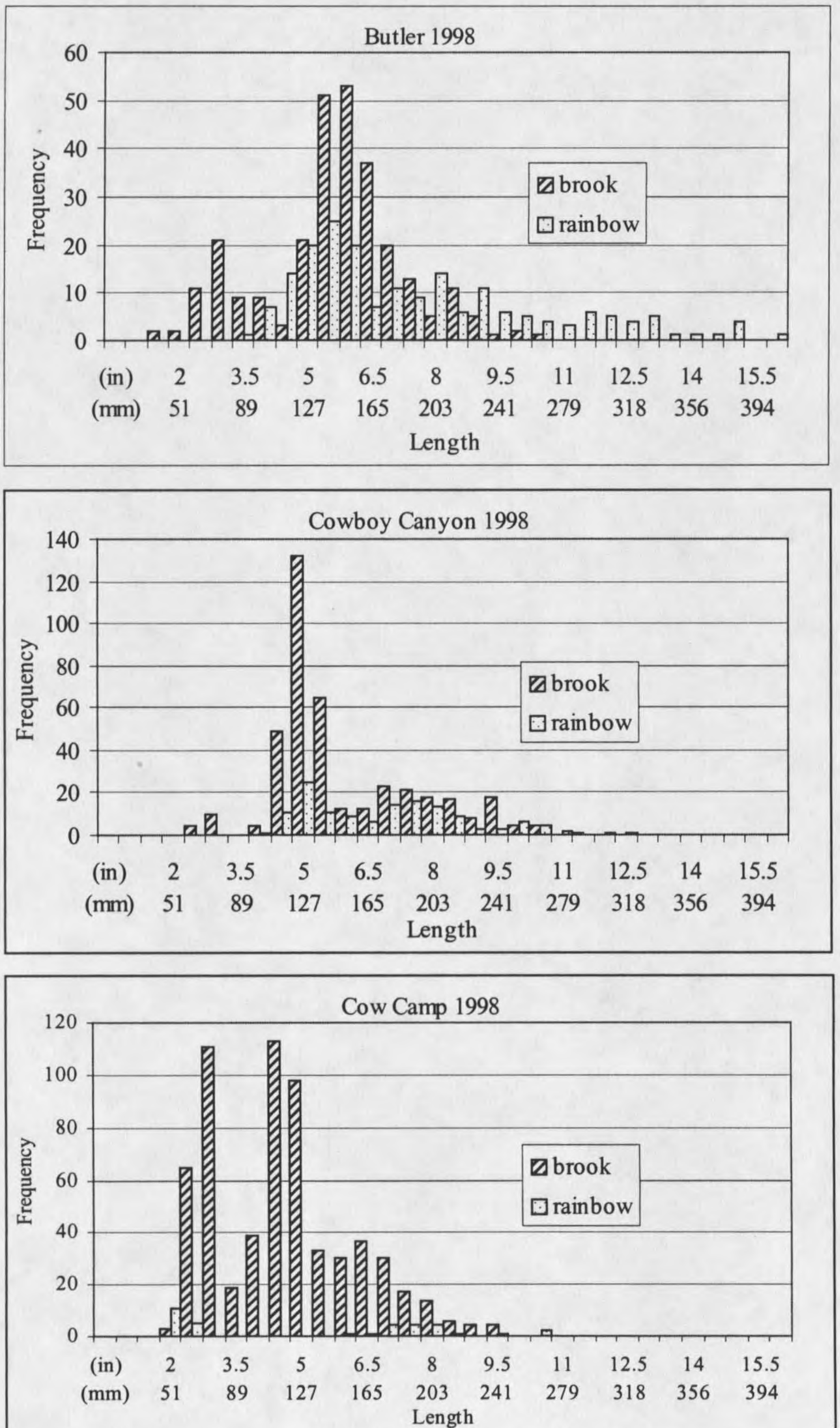
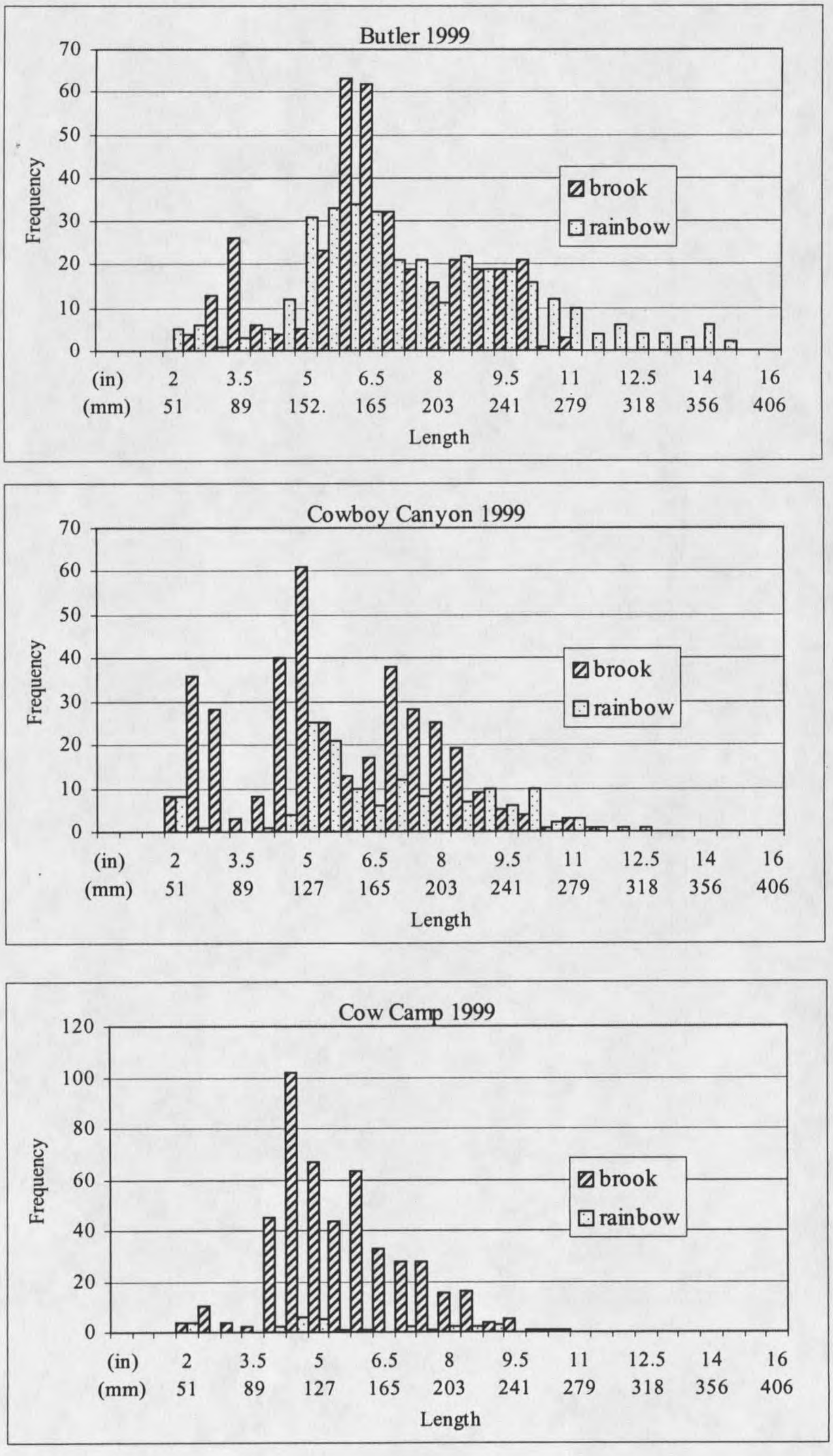


Figure 7. Length-frequency histograms for the three sections, 1999.



these sections age 1 rainbow trout ranged from approximately 90 to 205 mm (3.5 to 8 inches) long in 1998 and 1999, with the rainbow trout from the 1999 Butler section representing the longer lengths.

The distributions of lengths comprising peaks in the histograms become broader and less distinct for fish older than age 1. Determining definitive ranges of lengths for these older age classes from length-frequency histogram examination alone illustrates a common shortcoming of length-frequency histograms; which is that for many fish populations, another method of aging must be employed in order to correctly determine lengths-at-age for older age classes. However, trends such as the greater number of larger rainbow trout in the Butler and Cowboy Canyon sections are apparent by comparing the respective histograms. Another trend evident is the increase in the numbers of age-1+ brook trout in the Butler section from 1998 to 1999. The decrease in age-0 brook trout in the Cow Camp section from 1998 to 1999 is suspect as the capture efficiencies for this size class are low.

Fish Population Characteristics

Age

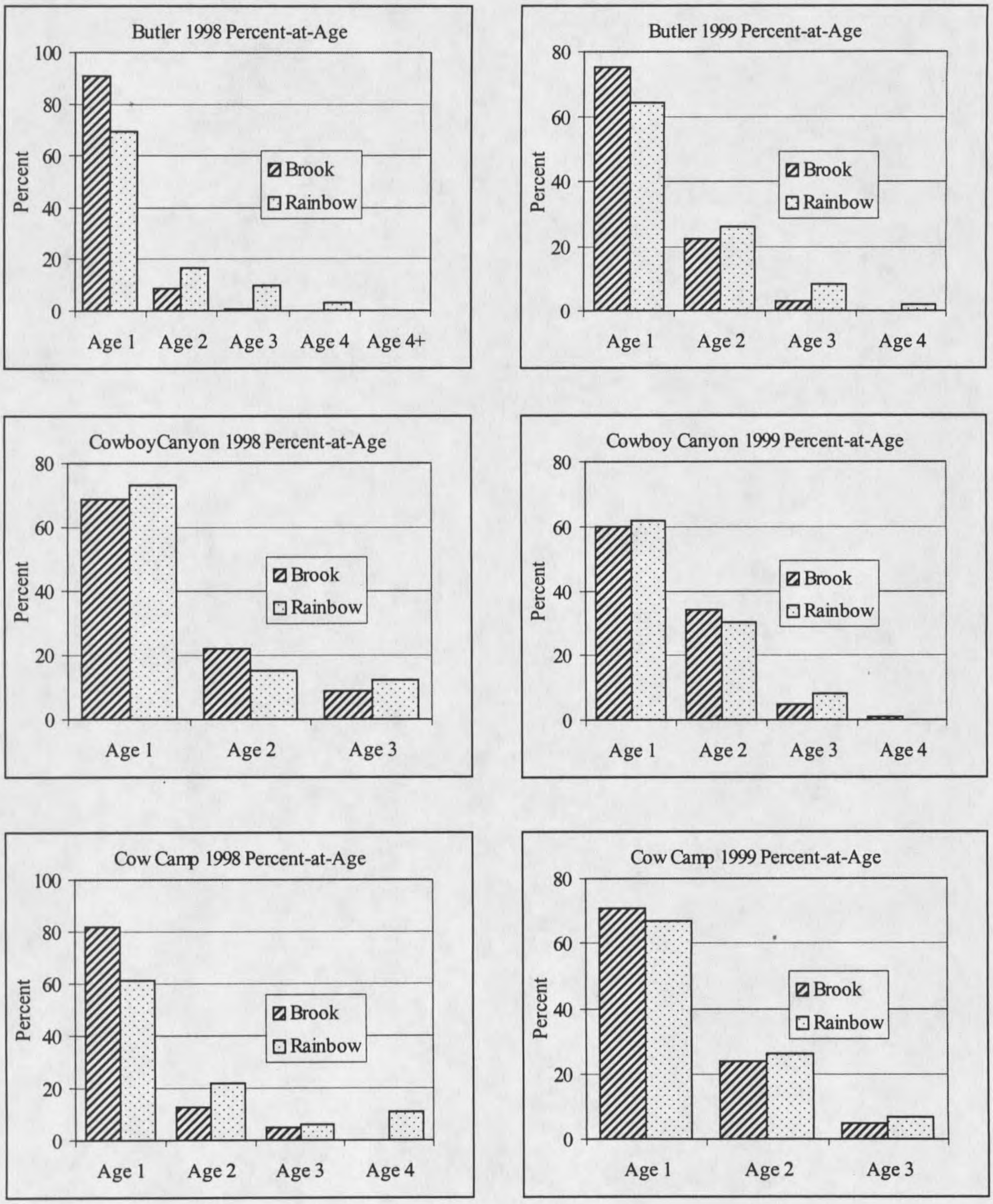
Ages interpreted from scales form fish of various lengths were compared with peaks of associated length-frequency histograms (Figures 6 and 7) for the smaller size and age classes, and with otoliths for the larger size and age classes (Appendix B). Ages interpreted from scales corresponded closely to the peaks in length-frequency histograms for respective species, sections and years for ages 0, 1 and 2, while otolith readings supported scale readings for older fish. Ages of fish from respective size-classes were then used to construct age-length keys for respective species, sections and years (Appendix C).

Examination of scales and otoliths indicated that the trout communities were comprised of fish ages 0 through 4, with very few being found to be age 4. Examination of otoliths indicated that only one specimen was four years old, and this was one of the largest fish captured at 380 mm (Appendix B). Of the 248 fish that were aged using scales, only 8 or 3.2 %, were aged to four years (Appendix C). Although some larger fish were not aged due to regenerated scales, the length-frequency histogram, scale reading, and otolith data all suggest that this paucity of fish older than age 3 is an accurate characteristic of the populations in the study sections. The single largest fish, a rainbow trout 419 mm (16.5 inches) long from the 1998 Butler estimate, appeared as an outlier in the respective length-frequency histogram (Figure 6) and was therefore assigned age 4+. Because the scales sampled from this fish were regenerated and no otoliths were taken during 1998, its age could not be determined.

Percent-at-Age

Due to the inefficient capture for the age-0 size-class of fish, percent-at-age estimates were only calculated for age 1 and older fish (Figure 8). Although this omission fails to describe the contribution of age-0 fish to the community, comparisons of the relative contributions of the older ages to the population are still valid.

Figure 8. Percent-at-Age of brook and rainbow trout for the three sections in 1998 and 1999.



Trout communities were composed primarily of young fish, less than 3 years in age (Figure 8). One trend that was consistent for both years was that rainbow trout in the Butler and Cow Camp sections had a larger percentage of their total ages in the older (age 2 and above) age classes than the brook trout did in these sections. Rainbow trout had a higher proportion of age-3 fish than did brook trout in all instances. Apart from the decrease in percentages of age-1 fish in the Butler section from 1998 to 1999, the percent composition among ages remained fairly consistent throughout.

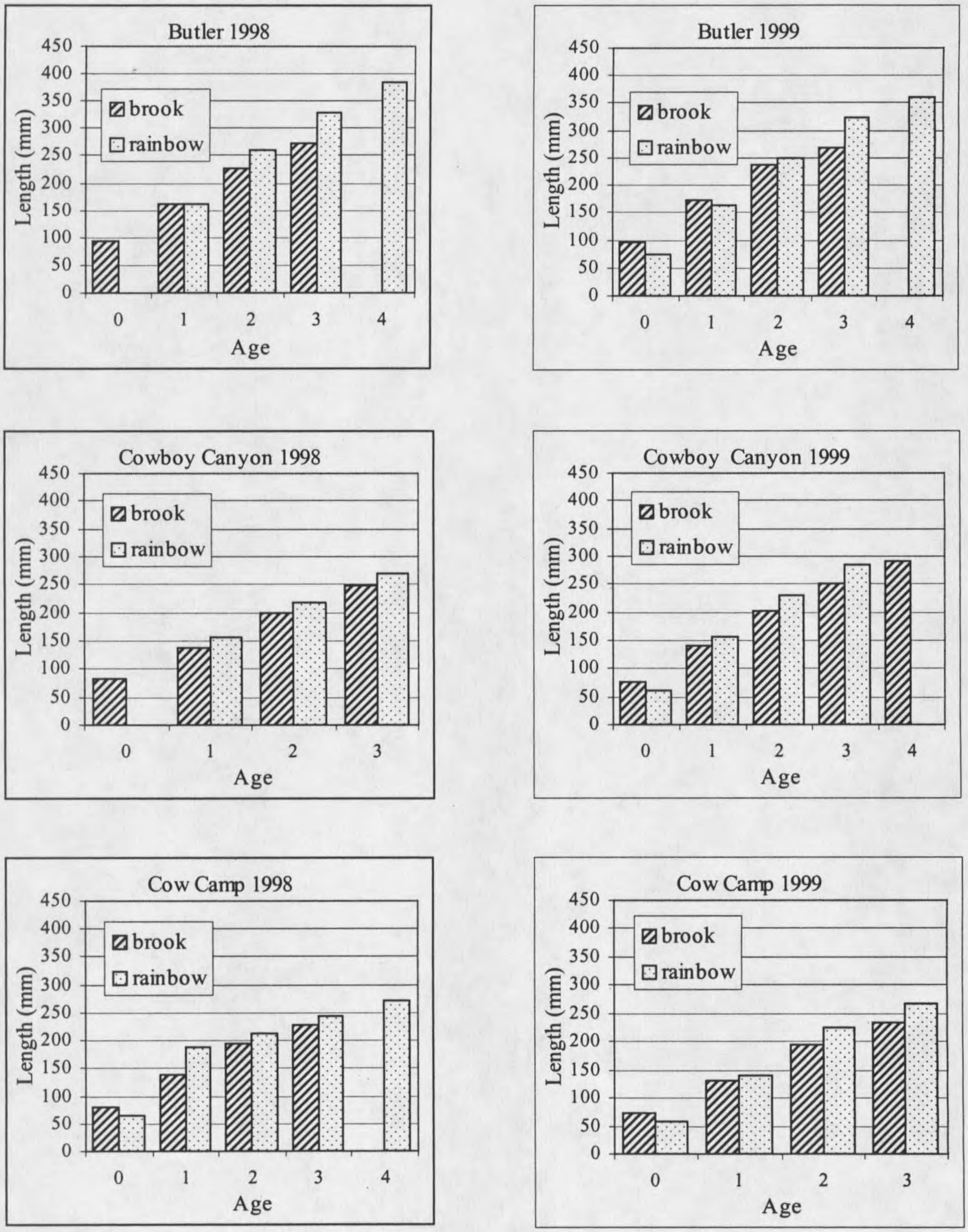
When the percent-at-age for each species in each section for ages 1 through 3 where averaged over the two years and compared against like ages, only one difference was found to be significant. The small percent-at-age for age-3 brook trout in the Butler section was found to be significantly less than the percent-at-age-3 for rainbow trout in the Cowboy Canyon section.

Mean Length-at-Age

After determining ages for a subset of fish in various size classes and creating an age-length key (Appendix D), ages were assigned to all fish. Means of the lengths in respective age classes for each species, section and year determined mean length-at-age. In sections where age-0 sized fish were captured, mean length-at-age values were calculated for all ages.

Rainbow trout had larger mean lengths-at-age than brook trout, except for age-0 fish, and age-1 trout in the Butler section (Figure 9). For example, age-2 rainbow trout

Figure 9. Mean length-at-age (mm), of brook and rainbow trout for the three study sections in 1998 and 1999. The Butler section in 1998 had one 419 mm, 4+ year-old rainbow trout that was not included.



from the three sections over the two years ranged in length from 213 to 262 mm, whereas brook trout were 196 to 234 mm long at age 2. The average difference between age-2 brook and rainbow trout over the two years was 21 mm. At age 3 this difference is more apparent, with rainbow trout ranging in length from 244 to 330 mm versus brook trout that ranged from 229 to 272 mm long, with the average difference of 36 mm between the two species.

Except for age-1 rainbow trout being larger in the Cow Camp section in 1998, another trend was the overall decrease in mean length-at-ages for both species during both years in an upstream direction (Figure 9). In one instance this resulted in the mean length-at-age for age-2 brook trout from the 1998 Butler section being not statistically different from mean length-at-age of age-3 brook trout from the 1998 Cowboy Canyon section (results of a two-sample T-test; $\alpha = 0.05$).

A Tukey's pairwise comparison procedure under one-way ANOVA was used to test all pairwise comparisons of means of lengths captured fish within the same age. These comparisons were run between species, between sections, and between years. Displaying all these comparisons is not practical; instead, the following summary of the trends found in the analysis provides a better illustration of the important differences.

Because of the larger sample sizes for within age 1, and within age 2, comparisons, relatively small differences between species, between sections, and between years were often deemed significant. As sample sizes (and degrees of freedom) decreased, findings for significant differences became less common. For example, within the age 1 comparisons, differences as small as 10 mm (0.4 inch) were found to be significantly different. However, in the less well represented age 3 group, differences as large as 26 mm (1.04 inch) were found to be insignificant. As a result, while approximately two-thirds (68 %) of the within age 1, and within age 2, comparisons were significantly different, the percentage decreased to 50 % for the age 3 comparisons, even though differences within this age class were more pronounced (Figure 9).

Back-Calculations and Growth Estimates

Scales from many older fish were regenerated and could not be used; however, back-calculations were performed for 248 samples (Tables 5 and 6). Reported back-calculated increments for age classes not followed by an additional age were pessimistic as the derived length represents distance between last annuli and scale margin and was therefore not representative of an entire years' growth (Carlander 1969). Therefore, complete back-calculated annual growth estimates for the 1998 season ranged from 25.7 mm for age 3 brook trout in the Cow Camp section, to 79.6 mm for age-1 rainbow trout from the Butler section. The complete back-calculated estimates for 1999 displayed a slightly broader range, from 17.4 mm for age-1 brook trout in the Cow Camp section, to 82.3 mm for age-2 rainbow trout in the Butler section (Figure 10). Growth estimates from differences in mean length-at-age were available for fewer age classes and for the 1999 season only (Table 6). These values were slightly larger and ranged from 30.5 mm for age-3 rainbow trout from the Butler section, to 86.3 mm for age-1 rainbow trout, also from the Butler section.

Table 5. Mean back-calculated annual growth increments for age class (mm), for the three sections in 1998.

		1998			
Section	Species	Age 1	Age 2	Age 3	Age 4
Butler	Brook	61.6	25.7	34.4*	
	Rainbow	79.6	72.5	37.1*	
Cowboy Canyon	Brook	38.8	38.6	22.4*	
	Rainbow	64.4	64.3	34.8*	
Cow Camp	Brook	40.3	37.3	27.1*	
	Rainbow	31.3	35.5	25.9	13.4*

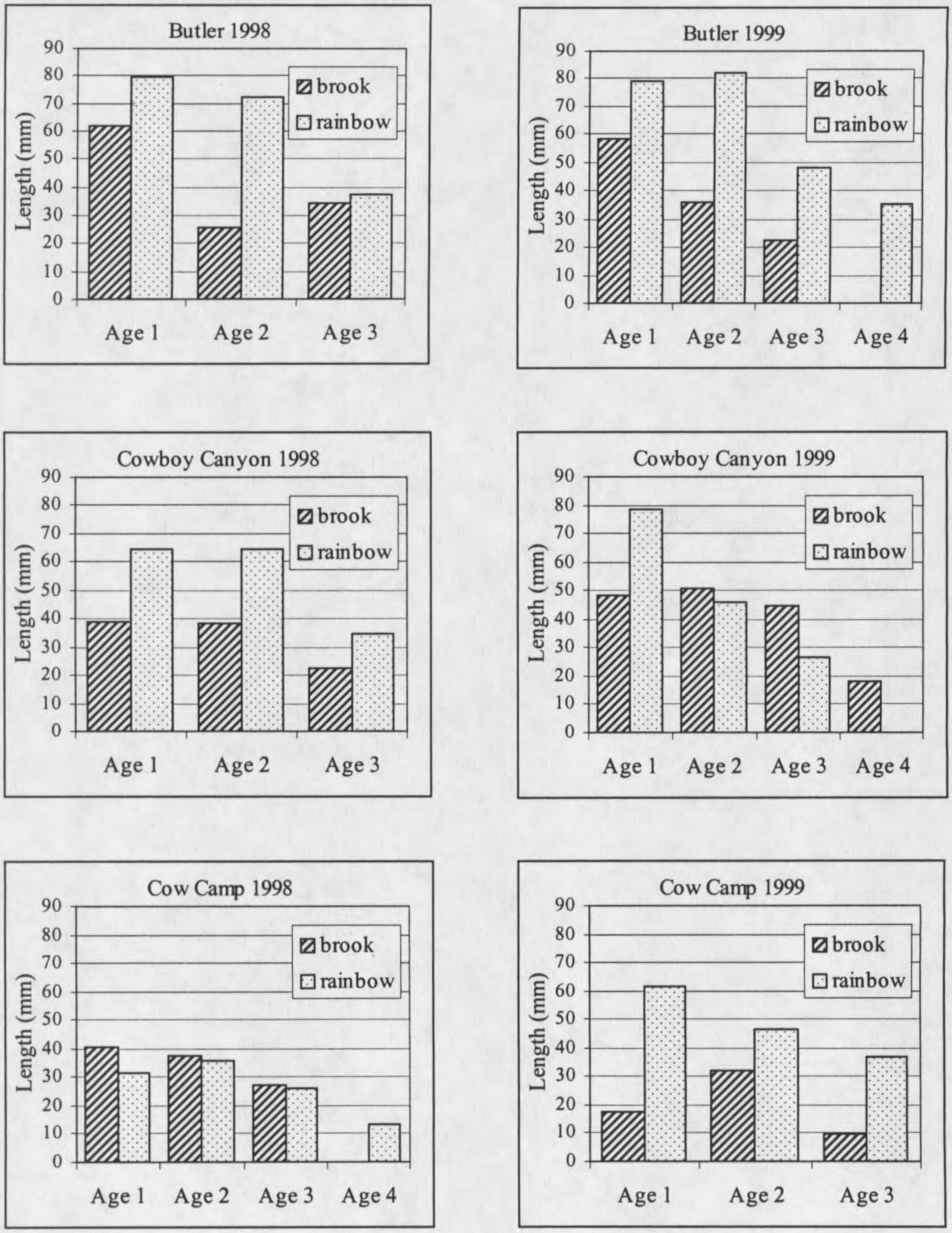
* Designate incomplete back-calculated annual growth increments, based on increments determined from annuli at last age and scale margin, see methods.

Table 6. Mean back-calculated annual growth increments for age class (mm) for the three sections in 1999. Annual growth from differences in mean length-at-age from consecutive age-classes from consecutive years (mm), in parenthesis.

			1999			
Section	Species	Age 0	Age 1	Age 2	Age 3	Age 4
Butler	Brook		58.4	35.7	22.6*	
		(78.7)	(76.2)	(43.1)		
	Rainbow		79.1	82.3	48.2	35.5*
			(86.3)	(61.0)	(40.7)	
Cowboy	Brook		48.3	51.0	44.6	18.1*
Canyon		(58.4)	(66.0)	(53.5)	(30.5)	
	Rainbow		78.3	46.1	26.3 *	
			(73.6)	(68.6)		
Cow	Brook		17.4	32.1	9.4*	
Camp		(50.8)	(58.4)	(38.1)		
	Rainbow		61.5	46.4	37.0*	
		(76.2)	(35.5)	(53.3)		

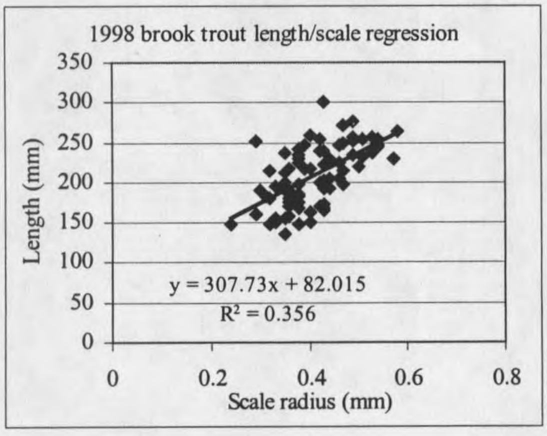
* Designate incomplete back-calculated annual growth increments, based on increments determined from annuli at last age and scale margin, see methods.

Figure 10. Mean back-calculated annual growth increments for age class in millimeters for the three sections in 1998 and 1999.



The larger growth rate based on mean length-at-age suggests a possible bias in the back-calculated lengths. To determine if this was the case, back-calculated lengths-at-age for each age group were compared (Appendix E). Apart from two exceptions, rainbow trout in the 1998 Cowboy Canyon and Cow Camp sections, back-calculated mean lengths-at-age were greater for older fish. This is known as reverse Lee's phenomenon and may have been a symptom of a biased intercept parameter of the associated length/scale regression (Figures 11 and 12), or that faster growing individuals of the year class had lower mortality (Devries and Frie 1996). Although the R^2 values vary in the length-scale regressions (Figures 11 and 12), some were rather high; for example 0.80 for 1999 rainbow trout yet the associated back-calculations still showed the trend of reverse Lee's phenomenon. The low R^2 values for brook trout indicated a less precise relationship between scale radius and back-calculated length; thus, the reverse Lee's phenomenon observed for brook trout may well be a result of a biased intercept.

Figure 11. Length/scale regressions for each species when combined over the three sections for 1998.



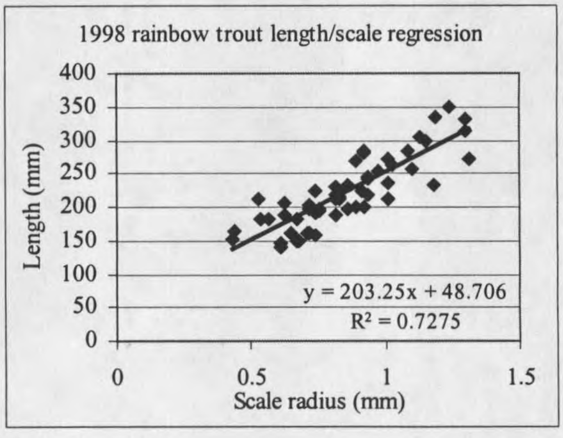
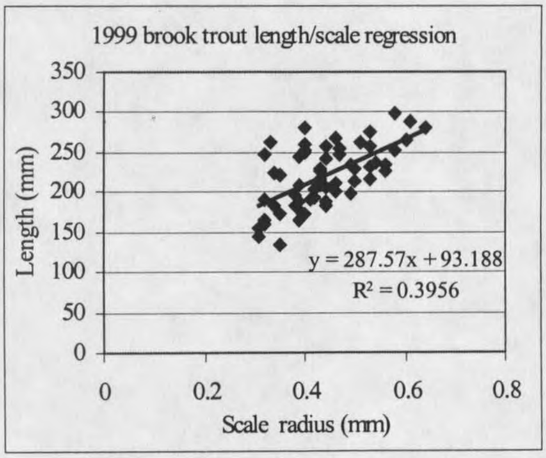


Figure 12. Length/scale regressions for each species when combined over the three sections for 1999.



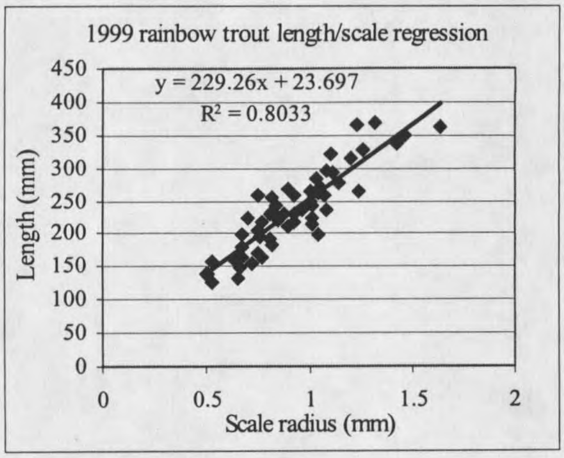


Figure 10 depicts the variability found in the back-calculated annual growth rates; expressed as annual increments in millimeters of back-calculated mean lengths-at-age. Although variable, one trend evident was that rates for rainbow trout, particularly in the Butler and Cowboy Canyon sections, represented the highest rates observed. Considering each year separately, Figure 10 shows that growth decreased for each species as the sections progressed in an upstream direction.

Because only age 1 and age 2 annual growth rates were complete, in terms of being derived from differences between annuli (see methods), only differences within these age groups were compared for differences between species, between sections, and between years. For the within age 1 comparisons, the high growth rates observed for the Butler and Canyon section's rainbow trout were significantly higher than the lower growth rates for other species and sections. The more variable Cow Camp section, with the associated large differences between the two year's annual age 1 growth estimates, represented the majority of the between year significant differences.

Fewer significant differences were found for within age 2 comparisons (42 % versus 50 % for within age 1 comparisons); this was due to less pronounced differences than to any decrease in sample size. For these age 2 comparisons Butler (and in 1998 Canyon) rainbow trout had significantly higher estimated annual growth rates. Although differences between the two years of the study were more pronounced for the within age 2 comparisons; only the decrease from 1998 to 1999 for Canyon rainbow and Cow Camp brook trout were found to be significant.

Condition Factor Estimates

Mean K values for fish greater than 100 mm in length were similar throughout all the sections and years. These values indicated that all sections had communities of fish in good condition, with K values consistently above 1.1 (Table 7). Although the values lacked much spread (the largest variation between mean K values was only 7 %) some patterns were still discernable. For example, rainbow trout had slightly higher K values in every instance, and the Cowboy Canyon section had the most variable values for both species over both years.

Table 7. Mean condition factor (K) for brook and rainbow trout 4 or more inches long for the three study sections in 1998 and 1999.

1998

Section	Species	n	Mean K	Standard Deviation	Code	Differs from
Butler	Brook	233	1.16	0.14	a	g,k
	Rainbow	191	1.17	0.16	b	c,e,g,h,k
Cowboy Canyon	Brook	388	1.13	0.19	c	b,i,j
	Rainbow	135	1.15	0.16	d	None
Cow Camp	Brook	426	1.12	0.15	e	b.i,j
	Rainbow	18	1.14	0.08	f	None

1999

Section	Species	n	Mean K	Standard Deviation	Code	Differs from
Butler	Brook	333	1.09	0.15	g	b,d,i,j
	Rainbow	328	1.11	0.14	h	b,i,j
Cowboy Canyon	Brook	297	1.17	0.22	i	c,e,g,h,j,k
	Rainbow	140	1.19	0.21	j	c,e,g,h,j,k
Cow Camp	Brook	452	1.10	0.13	k	a,b,i,j
	Rainbow	27	1.17	0.12	l	None

As was the case for mean length-at-age, the large sample size of individual K values enabled high precision (Table 7). Of note is that two of the three mean K values compared that were not significantly different were for rainbow trout in the Cow Camp section, with the other having been rainbow trout from the 1998 Cowboy Canyon section. This lack of difference can be attributed to mean values, for the 1998 Cowboy Canyon and Cow Camp sections, or low degrees of freedom, as was the case for the apparently high mean K value for rainbow trout in the 1999 Cow Camp section.

Mortality Estimates

Estimated annual mortality was consistently high and remarkably similar for all species, sections, and years, and ranged from 46.0% (95% CL ± 39.4%) to 91.4% in 1998 and 67.8% to 77.9% in 1999 (Table 8). Except for the Cowboy Canyon section, rainbow trout appeared to have lower rates of estimated annual mortality than brook trout. However, no significant differences were found in mortality estimates between species or sections when estimates were averaged over the two years.

Table 8. Estimated annual mortality for brook and rainbow trout in the three sections for 1998 and 1999.

1998			
Section	Species	Annual Mortality	95% C.I.
Butler	Brook	91.4%	± 3.6%
	Rainbow	67.6%	± 5.6%
Cowboy	Brook	71.3%	± 15.3%
Canyon	Rainbow	72.0%	± 6.6%
Cow	Brook	84.7%	± 3.2%
Camp	Rainbow	46.0%	± 39.4%

1999			
Section	Species	Annual Mortality	95% C.I.
Butler	Brook	77.9%	± 4.3%
	Rainbow	67.9%	± 4.2%
Cowboy	Brook	67.8%	± 3.2%
Canyon	Rainbow	68.5%	± 6.5%
Cow	Brook	74.7%	± 3.5%
Camp	Rainbow	70.3%	± 11.8%

Correlations between Macrohabitat and Fish Parameters

Simple linear regression was used to test for correlations between selected macrohabitat parameters and fish demographic parameters and population characteristics

(Tables 9 and 10, Appendix F). Percent of reach length comprised of slow-water habitat (percent pool), pool volume, and channel gradient (percent) were found to have significant correlations with certain fish demographic (Table 9) and population characteristics (Table 10). Of the macrohabitat parameters compared, channel gradient had the largest percent of significant correlations 72 %, followed by pool volume and percent pool, at 50 and 17 % respectively.

Table 9. Summary of significant correlations between selected Macrohabitat parameters and fish demographic parameters.

	Macrohabitat parameters			
Demographic Parameters	Percent gradient Relationship	R^2	Pool Volume Relationship	R^2
No. of EBT/ km	Positive	0.89	none	
No. of RBT/ km	Negative	0.85	Positive	0.79
EBT percent comp.	Positive	0.98	Negative	0.76
RBT percent comp.	Negative	0.99	Positive	0.76
RBT Biomass	Negative	0.85	Positive	0.83

Fish demographic parameters were not significantly influenced by percent pool, but were strongly correlated with percent gradient and pool volume. Species' percent contributions to community make up were strongly correlated with gradient, with the relationship having been negative for rainbow trout, and positive for brook trout. Pool volume was positively correlated with rainbow trout numbers, percent composition, and biomass (Appendix F) while negatively correlated with brook trout percent composition (Table 9).

Table 10. Summary of significant correlations between selected Macrohabitat parameters and fish population characteristics.

Population Characteristics	Macrohabitat parameters					
	Percent Gradient		Pool Volume		Percent Pool	
	Relationship	R^2	Relationship	R^2	Relationship	R^2
EBT mean length-at-age 1	Negative	0.82	Positive	0.95	Positive	0.82
EBT mean length-at-age 2	Negative	0.72	Positive	0.94	Positive	0.80
EBT mean length-at-age 3	Negative	0.97	Positive	0.82	none	
RBT mean length-at-age 2	Negative	0.67	Positive	0.87	Positive	0.73
RBT mean length-at-age 3	Negative	0.83	Positive	0.89	none	
EBT back-calc. growth age 1	Negative	0.74	none		none	
RBT back-calc. growth age 1	Negative	0.66	none		none	
RBT back-calc. growth age 2	Negative	0.79	Positive	0.75	none	

Table 10 illustrates the negative relationship that percent gradient had on all of the fish population characteristics that were significantly correlated. Pool volume was found to have positive effects on most of the fish population characteristics. Surprisingly, given this and other studies' propensity in equating amount of pool habitat to overall habitat quality, the percent pool habitat parameter had the fewest positive relationships of the significantly correlated fish population characteristics.

DISCUSSION

Macrohabitat Parameters

This study emphasized the lower section of Cherry Creek because these lower gradient areas contained the best overall habitat for the restoration of westslope cutthroat trout and the possible restoration of Arctic grayling (Bramblett 1998, Kaya 1992). This availability of quality, low gradient habitat in lower Cherry Creek addresses the call for restoration projects to incorporate systems larger and more productive than the headwater streams typically used in restoration projects (Probst et al. 1992, Harig et al. 2000, Hilderbrand and Kershner 2000, Shepard and Spoon 2000).

Trout distribution and abundance has been positively correlated with the amount and quality of pool habitat (Lewis 1969, Ireland 1993, Herger et al. 1996). Pool:fast-water (riffle and run) ratios per unit length for lower Cherry Creek ranged from roughly 1:3 (32.4 % pools) in the Butler Reach to 1:5 (19.8 % pools) and 1:4 (23.4 % pools) in the Cowboy Canyon and Cow Camp reaches. Pool:fast-water ratios were not as high as those observed in other streams, for example the 1:2 to greater than 1:1 ratios for headwaters of the Taylor Fork drainage (Ireland 1993), but compared favorably to the approximate average percentage of pools (20 %) reported for another westslope restoration site, Muskrat Creek (Shepard and Spoon 2000). The abundance of pools in lower Cherry Creek was even more impressive given that percentage of pool habitat has been found to decrease with gradient and increased stream order (Platts 1979). Pool abundance alone does not accurately portray the relative quality of habitat found in a reach. However, when specific pool habitat measurements, such as mean maximum depth, percent fines (percent of substrate comprised of sediment), large woody debris numbers, and residual pool volume are included, the quality of the slow-water habitat in lower Cherry Creek can be further appreciated (Table 2 and Appendix A).

With between 19 to 25 % of all habitat classified as runs (non-turbulent, fast-water habitat types) in the three principal reaches, fast-water habitat also became an important component in the overall habitat quality of lower Cherry Creek. This feature is particularly important considering that densities of westslope cutthroat trout in non-turbulent fast-water habitat types can approach those found in pools (Ireland 1993, Herger et al. 1996).

Within the reaches selected, macrohabitat parameters were measured in accordance with Level II inventory protocol for the R1/R4 Fish Habitat Inventory Method (Overton et al. 1997). The measurements taken, and the ensuing F-Base reports generated (Appendix A), allowed quantitative comparisons on the nature of the habitat found in the three principle reaches. The use of a standardized and widely employed fish habitat inventory system will facilitate comparisons with like habitat parameters measured as part of a future survey of westslope cutthroat trout restoration in Cherry Creek.

The extent to which these habitat parameters change between reaches may then be related to population parameters of the restored population of westslope cutthroat trout. Overton et al. (1997) state that the habitat parameters collected can be used to identify factors limiting fish populations, define current and potential status of fish habitat, correlate fish and fish habitat distributions and conditions with environmental parameters, past and present land use, and natural disturbance. Macrohabitat parameters selected for their significant correlation with fish demographic parameters and population characteristics are discussed below.

Fish Demographic Parameters

Population Estimates

Two-pass depletion methodology is recognized as a viable estimation method in small streams when a large percentage of the fish (greater than 75 to 80 %) are removed in the first pass (Zippin 1958, Seber and Le Cren 1967, White et al. 1982). However, when employing only two passes, consistency of capture probabilities between passes cannot be tested. This shortcoming is in obvious conflict with one of the assumptions of the depletion model, that capture probabilities are constant for all passes. Depletion population estimates that are calculated by regression based on this assumption will often underestimate the actual number of fish (Mahon 1980, White et al 1982, Riley and Fausch 1992). However the high initial capture probabilities and the estimate's narrow standard error values (Tables 3 and 4) infer that the population estimates were accurate as possible given the use of the two-pass method (Zippin 1958, Seber and Le Cren 1967, Mahon 1980, Raleigh and Short 1981). Comparison to simulations presented by Riley and Fausch (1992) suggest that the capture probabilities and population estimates involved in this study produced estimates that were from 2.5 to 11 % lower than the actual population.

A major shortcoming of electrofishing in general is that young-of-the-year fish are known to have much lower capture probabilities than larger fish (Raleigh and Short 1981, White et al. 1982, Riley and Fausch 1992, Reynolds 1996). This problem was mediated somewhat by the excluding age-0 fish from population estimates (Tables 3 and 4).

The Butler estimates stood out as the least accurate in terms of standard errors and capture probabilities. In this instance, the 1999 estimate is 28 % larger than the 1998 estimate. Part of this increase can be attributed to the above-mentioned propensity for two-pass depletions to underestimate the actual population. Also the natural variation in fish populations typical in small streams may be a factor (Platts and McHenry 1988, Probst and Stefferud 1997). Finally, the 1999 depletion estimate was conducted later, in mid-September as opposed to August, and it is possible that fish moved to the larger, refuge areas in the Butler section in late summer, as has been reported by others (Herger et al. 1996, Shepard et al. 1998, Young 1995).

In all likelihood the observed differences were probably due to a combination of the above factors. However, by comparing the depletion estimates for the Butler section to modified Peterson mark-recapture estimates also gathered in the Butler reach by Inter-Fluve (1990), some idea of the cause for the observed variation may be discerned. For comparison purposes the Inter-Fluve estimates were also revised by omitting the smallest, under-represented size class. However because the Inter-Fluve survey was conducted in

April, their age-1 fish were of comparable length to age-0 fish in this study's depletion estimates. Comparing the revised estimates reveals a markedly higher Inter-Fluve estimate in 1990: 3,517 fish per km (5,627 per mile), versus this study's estimates of 1,285 per km (2,068 per mile) for 1999 and 927 fish per km (1,492 per mile) for 1998. At first glance this comparison suggests that this study's population estimates for the Butler section were grossly underestimated; however as will be seen later in the discussion, when other demographic parameters are compared this discrepancy became much less pronounced.

Unfortunately, there were no Inter-Fluve estimates conducted above the Butler section to provide other comparisons with this study's depletion estimates performed in the upstream sections. However, the much smaller and simpler habitat, in terms of lower residual pool volumes (Table 2), and higher capture probabilities for the depletion estimates in these sections, suggest that these estimates and the parameters derived from them, can be considered fairly accurate (Riley and Fausch 1992).

Overall, the population estimates reflect the high numbers of fish found throughout the lower gradient areas of Cherry Creek. Cherry Creek population estimates compared favorably to estimates from tributaries higher in the Madison River drainage (Sloat et al. 2000), which had a mean of 109 trout per km (175 per mile) and a highest estimate of 525 trout per km (845 per mile). Comparisons to O'Dell Creek, a more productive (spring-fed) Madison River tributary which had 611 trout per km (984 per mile) (Vincent 1987); and to revised estimates from Spanish Creek, another similar-sized stream also found on the Flying D Ranch, which had 658 trout per km (1060 per mile) (Inter-Fluve 1990), further illustrates the high number of trout found in Cherry Creek.

Density Estimates

Density is widely considered to be an important measure of a stream's health and productivity (Platts and McHenry 1988). Because density is determined by dividing population estimates by area, less intrusive methods such as snorkeling, where only counts are recorded, can be used to estimate this parameter. This is an important consideration when sampling endangered or threatened species, remote areas, or where time or budget constraints make collection of individual fish measurements impractical (Hankin and Reeves 1988, Overton et al.1997). Due to its relative ease of collection, density is a common measure of relative abundance and is often used for comparative purposes (Platts and McHenry 1988, Herger et al. 1996, Probst and Stefferud 1997).

The mean density for combined revised estimates over both years was 0.142 fish per m^2 (1,420 fish per hectare). This value falls within the range given by Platts and McHenry (1988) for the Rocky Mountain Forest region but is much lower than the mean of 0.55 fish per m^2 (5,500 fish per hectare). Because the standard deviation associated with this mean was high, 0.67 fish per m^2, more meaningful comparisons were made with specific examples, such as the values of 0.03 to 0.26 trout per m^2 (300 to 2,600 per hectare) for a sympatric community of brown and rainbow trout from Little Prickly Pear Creek (Platts and McHenry 1988). Handy (1997) found late autumn densities of westslope cutthroat trout in Cache Creek to be 6,400 trout per hectare (0.64 trout per m^2)

in prime overwintering habitat. Horan et al. (2000) estimated densities of 0.038 to 0.139 fish per m^2 (380 to 1,390 fish per hectare) for Colorado River cutthroat trout. A sympatric community of brook and westslope cutthroat trout in White's Creek, ranged from less than 500 to nearly 5,000 trout per hectare (Shepard and Spoon 2001).

As these examples illustrate, care should be used in comparing estimates of density, as they can be more variable than biomass estimates and are subject to change according to migrations and physical dimensions of the habitat (Shepard and Spoon 2001). The large values for the Cache Creek example, due to the small size of the system and the concentration for a limited habitat, serves to illustrate the care needed when comparing densities between seasons. Variability is again decreased when species' percent contribution to total density is examined. This parameter clearly defines the makeup of the community and provides an easy form of comparison (Figure 4).

Biomass Estimates

When expressed as kg per hectare, biomass (often referred to as standing crop) is used to assess carrying capacity (Behnke 1992, Ney 1999), and is often less variable in nature than other parameters. Hence biomass is frequently the parameter of choice when an evaluation of system health, management activities, and inter-system comparisons is needed (Scarnecchia and Bergersen 1987, Platts and McHenry 1988, Shepard and Spoon 2001). The results of this study supported the importance and less variable nature of biomass as well. Biomass had less variability than other parameters such as population numbers, mean length-at-age, percent-at-age, and to a lesser extent density, in comparisons between species, sections, and years.

This variability was lessened further when the percentage of each species contribution to biomass was considered (Figure 5 Appendix B). It is in examining this aspect of biomass that complex biological factors such as resource partitioning and competition may be isolated and investigated for their effect on the community in question. As was suggested by the relatively constant percent of species' contribution to total biomass between species and years for each reach, some form of biological control and niche partitioning may have been occurring to keep these relative contributions in a state of equilibrium (Nilsson 1967, Cunjak and Green 1984). However, in studies of restoration projects where pre-restoration (sympatric) biomass estimates were compared to the restored (allopatric) biomass estimates, the two were found to be similar (Moore et al. 1983, Platts and McHenry 1988, Shepard and Spoon 2001). The biomass data collected in this study should allow comparisons between the existing trout community and the restored westslope cutthroat trout population to determine whether a population of a single species does indeed have as high a standing crop as a sympatric community.

Estimated total biomass of brook and rainbow trout in the study sections ranged from about 7 to 15 grams per m^2 over both years (Figure 5, Appendix B). The biomass estimates for the Butler section were compared to estimates collected by Inter-Fluve in April of 1990. As in the population estimates, Inter-Fluve biomass estimates were revised to exclude the youngest, under-represented age-class. Converting the revised Inter-Fluve combined biomass estimate for the Butler survey from pounds per mile to grams per m^2 (using surveyed Butler mean width) resulted in an estimate of 16 grams per m^2, as opposed to 9.4 to 15.2 grams per m^2 for the 1998 and 1999 estimates. Thus, when biomass estimates are compared, differences between the 1990 survey and this study became much less pronounced.

Cherry Creek's mean of 9.6 grams per m^2 for all combined biomass estimates, compares favorably to the mean for the Rocky Mountain Forest Region of 7.7 grams per m^2 (Platts and McHenry 1988). This favorable comparison further illustrates the superiority of biomass as a parameter for quantifying a stream's population, as the density comparisons suggested Cherry Creek was less productive. A survey on Spanish Creek in 1990 (Inter-Fluve 1990), when converted to grams per m^2 and revised to exclude the under-represented, youngest age class, showed an average density of approximately 8.3 grams per m^2. Spanish Creek is a similar-sized stream adjacent to the Cherry Creek drainage (also located on the Flying D Ranch) and suggests that the Cherry Creek estimates are not atypical for the area. Shepard and Spoon (2001) reported biomass estimates of sympatric brook and westslope cutthroat trout populations in White's Creek ranged from less than 1 to over 11 grams per m^2. To see how Cherry Creek compared to other drainages, biomass estimates were converted to kilograms per kilometer. Combined revised estimates ranged from 50.8 to 132.9 kg per km with an overall average of 74.9 kg per km. These estimates compare favorably to those collected for a sympatric community of brown and rainbow trout in Deep Creek, which ranged from 7.88 to 39.24 kg per km (McClure 1991) but are much smaller than Vincent's (1987) estimate, which was 268.8 kg per km for brown trout in O'Dell Creek. Apart from the O'Dell Creek biomass, which was comprised of large fish from a very productive spring creek (Vincent 1987), and which could have been influenced by movement from nearby Ennis Reservoir, Cherry Creek's biomass estimates indicate a higher than average productivity for the region.

It is important to note that since biomass estimates are expressed as unit weight per area, calculated values are dependant on physical dimensions such as width:depth ratios; with shallower streams having lower values than deeper streams of the same surface area (Scarnecchia and Bergersen 1987). Therefore the higher biomass estimates for the Cowboy Canyon section, with its higher width:depth ratio, compared to the Cow Camp section (Figure 5, Appendix B), suggested that the Cowboy Canyon reach contributed more to overall production of lower Cherry Creek than was previously thought (Kaya 1992).

Length-Frequency Distributions

The length-frequency distributions (Figures 6 and 7) provided insight on the size composition of the populations of brook and rainbow trout and how they compared between sections, years, and to other populations. Length-frequency histograms show relative strengths of each size class for each species, section and year. The much lower peaks for the later size classes suggested relatively high mortality, problems with past reproduction, or emigration of older fish. Mortality estimates presented later in this report may help explain this lack of larger (older) size classes. Also, the presence of larger (older) trout in the Butler section suggested that this section, perhaps due to its larger and deeper pools, provided the habitat needed to support these larger rainbow trout. Another difference between the length-frequency histograms was the decrease in abundance of rainbow trout in the upper two sections. Figure 6 also shows that a large percentage of the brook trout population in the Cowboy Canyon section in 1998 was comprised of age–1 fish; this may suggest favorable spawning conditions in 1996, or importance of this reach as a possible nursery area. Also apparent was that age-2 brook trout in the Butler section, represented by the third node: approximately 220–260 mm (8.5–10.5 in) long, were much less abundant in 1998 than in 1999. This decrease could have been the result of excessive mortality of age-1 fish in 1997 or poor spawning recruitment in 1995.

Comparing overall shapes of length-frequency histograms between systems can provide insights into differences or similarities in population structure between systems. For example, the absence or depression of a year class in one system could infer that some process unique to that system resulted in the absence or depression of that year class. However, if this decline was similar between systems throughout a region, a wide-ranging affect such as climate may have been the cause. Differences in length-frequencies between systems may also show differences in growth rates or age structures between populations. For example, the distinct and widely separated peaks at relatively large sizes for age-1 and 2 trout in the Butler section indicated comparatively faster growth than most of the length frequencies compiled by Shepard and White (1998) for smaller, higher elevation westslope cutthroat trout streams. Conversely, comparisons of this study's brook trout length frequencies to those of brook and westslope cutthroat trout from lower elevation restoration projects (Muskrat and White's Creek, Shepard and Spoon 2000, 2001), taken at a similar time of year, depicted similar lengths-at-age for brook trout at ages 0 and 1 (30 to 70 mm and 80 to 130 mm respectively). Probably due to their later emergence as fry, length-frequencies for westslope cutthroat trout were smaller at ages 0 and 1 (under 50, and 60 to 100 mm respectively) than rainbow trout in Cherry Creek (Shepard and Spoon 2000, 2001).

Particular care must be taken to compare length-frequencies that were collected at similar times during the year (Shepard and White 1998). Problems in comparing length-frequencies taken at different times of the year can be seen by comparing the two season's histograms for the Butler section (Figures 6 and 7). The first two nodes for brook trout occurred at smaller lengths in 1998 than they did in 1999. This may be a result of differences in growth rate between the seasons or it may have been due to the fact that the lengths were collected 4 weeks later in the growing season (September 17 versus August 25) in 1999.

Other problems inherent in length-frequency data can be seen by examining the length-frequencies for rainbow trout (Figures 6 and 7). The nodes for this species were much less "peaky" and as a result separating age or size classes and hence determining such trends as growth, or comparing lengths-at-age, became much more problematic. It is due to problems like these that length-frequency histograms are considered useful for showing overall population structure and trends but, other data should be provided to support definitive conclusions (Anderson and Neumann 1996, Shepard and White 1998).

Fish Population Characteristics

Age

Scale and otolith readings, together with length-frequency analysis, confirmed that the sampled fish communities were comprised almost entirely of fish 3 years of age or younger (Appendixes B and C). Comparisons to an earlier survey conducted on the Butler reach generally supported this finding, especially in the age structure observed for brook trout (Inter-Fluve 1990). Such short-lived populations are not uncommon for resident stream salmonid populations, especially brook trout (Carlander 1969, Whitworth and Strange 1983, Larson and Moore 1985). Westslope cutthroat trout populations however, typically have a much older age structure, with maximum ages of 8 years reported for some headwater streams (Downs 1995, Shepard et al. 1998)

An important factor determining longevity is age at maturity (Behnke 1992, Griffith 1999). Populations that spawn at an early age such as brook trout, where males in some systems spawn in their first season and all fish typically spawn in their second, are often comprised of fish 3 years old or younger (Carlander 1969, Larson and Moore 1985). Since sexual maturity is related more to fish size than to age, faster growth can result in early maturation and younger populations (Behnke 1992, Shepard et al. 1998, Griffith 1999). Conversely, the majority of westslope cutthroat trout from cold, and sterile headwater stream populations may not attain sexual maturity until age 3 or 4, at lengths of 110 to 180 mm (Downs 1995, Shepard et al. 1988). Genetics may also play a role in that some widely planted domestic strains of rainbow trout have been selected for earlier ages of maturity (Behnke 1992). It will be interesting to see if after restoration, a comparatively larger percentage of the restored westslope cutthroat trout population is comprised of older, larger fish. Many years of post-restoration monitoring may be needed to determine whether a different age structure is a lasting characteristic of the population (Harig et al. 2000), or merely a product of the restored population reaching equilibrium, as seemed to be the case for the population of westslope cutthroat trout in White's Creek (Shepard and Spoon 2001).

Percent-at-Age

Percent-at-age can relate a more accurate picture of population age structure than other means of comparison such as length-frequency distributions (Anderson and Neumann 1996, Shepard and White 1998). Evaluation of percent-at-age (Figure 8) supported the finding of a preponderance of young brook and rainbow trout. Age-1 fish comprised from 60 to 91 % of the population for both species, while age 3 and older fish made up form less than 1 to 12 %. Sample size for aging fish was low for some size classes because many of the samples taken, particularly those for larger fish, were found to be comprised of regenerated scales. However, given the focus on larger fish for otolith sampling and their support of scale readings (Appendix B), the low percentage of older fish should be considered as an accurate characteristic of the present trout community of Cherry Creek. Comparisons with future data should help in illuminating differences in population structure that may arise as a result of different mortality rates, age of sexual maturity, or longevity of the restored westslope cutthroat trout population.

Mean Length-at-Age

Mean length-at-age provides a measure of cumulative growth over time and is often regarded to be a product of habitat quality, in that fish from better habitat will grow faster and have greater lengths at a given age. Mean length-at-age can be used to estimate annual growth increments, provided multiple years of length and age data are recorded (Devries and Frie 1996).

The mean length-at-age estimates in (Figure 9) indicate that the brook and rainbow trout of Cherry Creek exhibited fairly rapid growth, especially for ages 0 through 2. Rainbow trout mean length-at-age ranged from 139.7 mm (5.5 inches) to 188.0 mm (7.4 inches) at age 1, from 213.4 mm (8.4 inches) to 261.6 mm (10.3 inches) at age 2, from 243.8 mm (9.6 inches) to 330.2 mm (13.0 inches) at age 3, and age 4 rainbow trout ranged from 271.8 mm (10.7 inches to 386.1 mm (15.2 inches). These lengths compared favorably to the approximate length-at-age listed by Brown (1971) for the species in Montana, which are: 76.2 mm (3.0 inches) at age 1, 203.2 mm (8.0 inches) at age 2, 279.4 (11.0 inches) at age 3, and 330.2 mm (13.0 inches) for age 4. Brook trout mean length-at-age ranged from 132.1 mm (5.2 inches) to 172.7 mm (6.8 inches) for age 1, from 195.6 mm (7.7 inches) to 238.8 mm (9.4 inches) for age 2, from 228.6 mm (9.0 inches) to 271.8 mm (10.7 inches) for age 3, and 289.6 (11.4 inches) for age 4. These lengths are greater than those give by Brown (1971) for the species in Montana: 76.2 mm (3.0 inches) for age 1, 152.4 (6.0 inches) for age 2, 203.2 mm (8.0 inches) for age 3, and 254 mm (10 inches) for age 4.

The mean length-at-age estimates in Figure 9 showed that for the two seasons of this study, rainbow trout were larger at ages 1 to 3 than were brook trout. The two exceptions to this both occurred for age-1 fish in the Butler reach; where perhaps some feature of the habitat, such as more abundant slow-water habitat, enabled higher early growth rates for brook trout in this reach as opposed to the upstream reaches (Cunjak and Green 1984). Due to their earlier emergence as fry, brook trout have a head start on rainbow trout, as was seen when comparing mean lengths-at-age 0, and actually have slower growth than rainbow trout for all ages.

Fish were generally smaller at age in the upstream sections (Figure 9). This suggested less favorable habitat in the upstream sections, as was also inferred by the physical habitat measurements and correlations (Tables 1, 2, 9 and 10).

Annual Growth Estimates

Annual growth increments calculated by differences in back-calculated mean length-at-age (Tables 5 and 6, Figure 10) and by differences in mean length-at-age between consecutive year classes in consecutive seasons (Table 6) produced slightly different results for age 1 and older trout. Both methods showed trends of comparatively slower annual growth for the later age classes, for brook trout compared to rainbow trout, and for trout of both species in the upstream sections. These trends are best illustrated by examination of the less variable and more complete back-calculated growth increments (Tables 5 and 6, Figure 10).

To determine how the annual growth rates from this study relate to rates in other systems, back-calculated increments were compared to those of similar systems compiled by Carlander (1969). These increments for brook and rainbow trout were from sympatric communities in waters of similar size (Prickly Pear Creek), geographic area (Gallatin River), or state wide averages (Carlander 1969). For example, growth increments for age 1 and age 2 rainbow trout in Cherry Creek ranged from 31.3 to 79.6 mm for age 1, 35.5 to 82.3 mm for age 2. While the upper range of these estimates were comparable to those compiled by Carlander, which averaged 91.7 mm for age 1 and 81.3 for age 2; averages for Cherry Creek were much smaller, 65 mm for age 1, and 57.8 for age 2. In addition, Cherry Creek rainbow trout were found to have comparatively much smaller growth increments for age 3. Back-calculated annual growth increments for rainbow trout in Cherry Creek averaged 37.1 mm as opposed to 67 mm for the average of the Carlander estimates. The brook trout in Cherry Creek exhibited an even greater disparity, with average increments of 44.1 versus 65.3 mm for age 1, 36.7 versus 81.3 mm for age 2, and 44.6 versus 61 mm for age 3. Because back-calculated length at first annulus formation represents growth from emergence until the following spring, these estimates are larger than actual growth for a young-of-the-year fish. Even despite this bias, young of the year trout in Cherry Creek exhibited high growth rates, and as a result, back-calculated mean length-at-age estimates for age 1 and 2 fish were comparable to those compiled by Carlander (1969) despite the slower growth for these age classes.

These findings of comparatively slower growth for older age classes were surprising given the high productivity of Cherry Creek, which was reflected in this study's high biomass estimates. The decrease in growth was also not accompanied by associated decreases in condition factors for the older age classes. This suggests that 2 and 3 year-old fish may have been investing more of their energy towards gamete production. Decrease in growth rates associated with gamete production, was found to be more common in older age classes, 3 through 5- year-olds, for resident salmonids in other systems (Carlander 1969). Although superficial, this evidence for early age at maturation could be confirmed by future investigations on fecundity of the present non-native trout community in Cherry Creek.

Condition Factor Estimates

Values for Fulton's condition factor (K) that are greater than 1.0 indicate fish of better than average condition (Carlander 1969, Anderson and Neumann 1996), according to this, trout in Cherry Creek were in better than average condition. Condition factor estimates for both species were consistently close to 1.1 (range 1.09 to 1.19) in all sections and for both years (Table 7). One interesting trend seen in the condition factor estimates was that rainbow trout had on average, significantly higher K estimates. This may reflect a competitive advantage that larger rainbow trout had over brook trout of the same age (Fausch and White 1981, Fausch 1988). This is because fish size is generally considered to confer a competitive advantage (Griffith 1972, Fausch and White 1981, Fausch 1988). As a result of this advantage, rainbow trout may be expected to have better condition factors due to their ability to out-compete the smaller brook trout for more energetically favorable habitat (Griffith 1972).

Condition factor estimates for the sampled fish communities of Cherry Creek were very similar to estimates from the Gallatin River: 1.03 for rainbow trout, 1.1 for brook trout; and Prickly Pear Creek: 1.1 for rainbow trout, 1.03 for brook trout (Carlander 1969). It is interesting to note that the estimates of K from the Inter-Fluve survey of the Butler reach were lower, with all values for fish of comparable size classes less than 1.0. This may reflect the rigors of overwintering or spawning since their survey was conducted in April, or it may be a product of the higher densities recorded for this survey resulting in increased competition. This difference illustrates an important consideration when comparing condition factor estimates, which is that K can change for various sizes of fish, life history, competition levels, and time of year captured (Carlander 1969, Anderson and Neumann 1996).

Mortality Estimates

Estimated annual mortality rates were consistently high for all species, sections and years. Although a less rigorous method for estimating annual mortality was used, estimates indicated a high mortality rate in this system (Table 8). Because age-0 fish were not used in the calculation, the annual mortality rate was estimated only for age 1 and older fish, and as such represented mortality rates that were higher than those normally observed for these age classes (Carlander 1969, Griffith 1999). Mortality rates as high as 90 % for resident stream salmonids are common for young-of-the-year, but generally decrease to levels lower than those found in this study for older age classes (Carlander 1969, Griffith 1999). Due to the private ownership, tightly controlled access, and low fishing pressure throughout the study sites, the relatively high mortality for larger and older fish cannot be attributed primarily to fishing mortality.

The high mortality rates and scarcity of older fish indicated that some process was affecting the older and larger fish, particularly rainbow trout. Possible causes for this apparently high natural mortality may have included biotic factors, such as predation and competition, and environmental factors, such as harsh summer or winter conditions and floods (Griffith 1999). These factors could have also acted in synergy, for example, effects of overwintering areas can involve both biotic (competition) and environmental (space availability) factors (Whitworth and Strange 1983).

The evidence for reverse Lee's phenomenon (Appendix E) hinted at the possibility that fish of larger size at a particular age may have enjoyed increased survival (Devries and Frie 1996). Since larger size confers more protection from predation and a competitive advantage, a biological factor may have influenced the mortality rates observed (Griffith 1972, Fausch and White 1981). Isolating biological mechanisms and how they may relate to increased mortality is problematic (Griffith 1988), and was not an aspect of this study. However, future study on responses of population characteristics, such as growth and survival, to density manipulations may help to isolate competition as a contributing factor to the high mortality present in this system.

Even with the evidence of reverse Lee's phenomenon, the observed high mortality for older and larger fish suggested that an environmental (abiotic) factor was primarily responsible for the high mortality rates observed. Overwintering mortality has been frequently cited as a major contributor to annual mortality rates for stream salmonids

(Whitworth and Strange 1983, Schrader 1989). However, this study did not find higher survival of trout in the Butler section, despite the abundance of deep, complex, overwintering pools, and the moderating affect of groundwater (indicated by large springs observed at the upstream end of the reach). Future surveys of biomass, densities, and age structure conducted before and after the winter season may help determine whether overwintering was the principal factor responsible for the high mortality rates observed (Whitworth and Strange 1983). Excessive summer mortality was also probably not a factor since the highest summer temperatures recorded during this study, approximately 17 ^{0} C, were well within the tolerance range for the trout community (U.S. Fish and Wildlife Service 1982). Indeed, the temperature regime of Cherry Creek was judged suitable for trout (Bramblett 1998). Apart from a drought during the summer of 1998, a review of U.S.G.S. hydrographs for the adjacent Gallatin and Madison rivers indicated flow regimes were near average for the years preceding this study and the survey conducted by Inter-Fluve in 1990. The low water year of 1998 may help explain the higher mortality estimated for brook trout in the Butler section that year. The difference in the Butler section's annual mortality rates between the two species for 1998 also suggested that abiotic factors (low flows and decreased volume) may have acted synergistically with biotic factors (predation and competition) because the larger rainbow trout did not exhibit disproportionately higher mortality. While interesting, this inference is merely speculation; for investigations into such complex interactions were not an aspect of this study.

The decline in older age classes might have also been the result of increased emigration rates for larger fish. Previous studies of salmonid populations and their movement patterns above waterfalls have dealt primarily with juvenile age classes (Northcote 1981, Chapman and May 1986, Deleray and Kaya 1992). High densities above falls and incomplete adaptation to remaining above falls, have been proposed as possible reasons for downstream movement over barrier falls in some instances (Chapman and May 1986, Deleray and Kaya 1992). It is possible that older, larger fish moved downstream out of the relatively small and densely populated reaches of Cherry Creek, and eventually moved over the falls. The lack of older and larger rainbow trout in the Cowboy Canyon and Cow Camp sections might been due to a similar one-way emigration over the diversion dam at the bottom of Cowboy Canyon reach. Although spring seeps bypass the diversion dam and probably allow for some upstream movement of smaller fish, it is doubtful that many larger fish can bypass the dam at most flows. In addition to future studies on age at maturity, mortality, and possibly competition, investigations into the movement of the restored westslope cutthroat trout population is needed as recent studies have found that stream salmonids may not be as sedentary as was previously accepted (Gowen et al. 1994).

Correlations between Macrohabitat and Fish Parameters

Regression analysis of selected macrohabitat parameters and fish parameters indicated strong relationships between percent channel gradient, pool volume, and percent pool with fish demographic parameters (Table 9) and population characteristics

(Table 10). Although macrohabitat parameters were taken from respective reaches and not from the sections, the relationships depicted help to illustrate the differences in the fish populations between the sections because the sections were representative of the habitat found in the respective reaches.

Macrohabitat parameters were selected for correlation based on their overall depiction of the reaches (sections) and on their importance over co-linear parameters for best defining the major differences between the reaches (sections) of lower Cherry Creek. Although parameters such as LWD numbers, percent substrate type, and others have been correlated with fish population demographics and characteristics (Scarnecchia and Bergersen 1987, Platts and McHenry 1988, Horan et al. 2000), these macrohabitat parameters appeared to be of secondary importance when analyzed with stepwise regression methods.

In particular, percent channel gradient appeared to be strongly correlated with the demographic parameters and population characteristics of the trout community in lower Cherry Creek. Rainbow trout numbers, percent composition, biomass, mean length-at-age, and growth were all negatively correlated with the increase in gradient (Tables 9 and 10, Appendix F). Conversely, brook trout became more abundant as gradient increased, although they too were negatively correlated in terms of smaller mean lengths-at-age and slower growth in response to the increase in gradient. This pattern in the demographic parameters reflects a pattern seen in the Smoky Mountains (Larson and Moore 1985) and central Idaho (Platts 1979). In these examples, rainbow trout are the more abundant species in the downstream and lower gradient areas, and after a short mid-section zone of transition, are replaced by brook trout in the higher gradient areas.

The concentration on the lower gradient areas of Cherry Creek was in part due to the recognition that this area provided a large amount of quality slow-water habitat. The regressions seemed to indicate that pool quality, in terms of volume, was more positively correlated with the demographic parameters and population characteristics of the trout community than was amount of pool habitat, as represented in percent pools. Both species had longer mean lengths-at-age and higher growth rates as pool volume increased. When the large advantage that the Butler reach has in terms of residual pool volume (114 versus around 70 m^3 for the other two principal reaches) is considered, the importance of this reach in providing quality habitat for the future restored westslope cutthroat trout population becomes much more apparent.

Summary

1. With low gradients of 1.0 to 1.5 %, slow-water habitats comprising 20 to 32 % of stream length, mean pool maximum depths of about 1.0 meter, low percent fines, an abundance of woody cover, and favorable temperature regimes, the three principal reaches of lower Cherry Creek provide over 9.2 km (5.7 miles) of excellent physical habitat for salmonids.
2. Combined numbers of brook and rainbow trout in 1998 and 1999 were 456 and 632 for the Butler section (927 and 1285 per km), 531 and 428 for the Cowboy Canyon

section (1037 and 835 per km), and 479 and 489 for the Cow Camp section (1190 and 1215 per km).

3. Combined density estimates increased from 0.105 to 0.147 trout/m^2 from 1998 to 1999 for the Butler section, decreased from 0.146 to 0.117 trout/m^2 in the Cowboy Canyon section, and remained similar for the Cow Camp section, with estimates of 0.166 and 0.170 trout/m^2 for 1998 and 1999, respectively.

4. Apart from the 1998 to 1999 increase in the Butler section (9.39 to 15.24 g/m^2), combined biomass estimates were similar within each section for the two years of the study with estimates of 9.21 to 8.59 g/m^2 in the Cowboy Canyon, and 6.99 to 8.10 g/m^2 in the Cow Camp section during 1998 and 1999, respectively.

5. Scale and otolith readings and length-frequency distributions indicated that populations of brook and rainbow trout in the three sections were composed almost entirely of younger fish, ages 1 to 3. There were very few (8) fish aged to four years or older among the 247 fish aged by scale and otolith readings.

6. Differences in mean back-calculated lengths-at-age, and in consecutive mean lengths-at-age of captured fish, indicated that both species grew relatively fast for ages 1 and 2, and slower for ages 3. Both methods of estimating annual growth showed that as a trend rainbow trout had higher growth than did brook trout, and growth for both species decreased in an upstream direction.

7. Condition factors were similar for both species in all sections over the two years of the study. Fulton's condition factor (K) values were typically slightly over 1.1 and indicated that all trout were in good overall condition.

8. Estimated annual mortality was consistently high for both species in all sections over the two years of this study, ranging from 46.0% (95% CL $\pm$ 39.4%) to 91.4 % in 1998 and 67.8 to 77.9 % in 1999.

9. When each reach's macrohabitat parameters were correlated with the respective section's fish demographic parameters and population characteristics, channel gradient had the largest percent of significant correlations, 72 %, followed by pool volume and percent pool, at 50 and 17 % respectively.

10. Future investigations of growth rates, age at sexual maturity, longevity, mortality, movement, and relationships to habitat for the restored westslope cutthroat trout population will provide further insights as to the suitability of this study's data for judging the relative success of the restoration, as well as providing a means to distinguish how the species concerned differ in their overall life strategies.

Conclusion

The Cherry Creek Native Fish Introduction Project will represent a major step towards reversing the decline of a native fish species, the westslope cutthroat trout. By providing a pre-restoration baseline survey of habitat and fish community parameters this project will add an element lacking in most restoration efforts. Previous restoration efforts employed pre-restoration surveys as a means for identifying distribution and abundance of the non-native species to better target eradication efforts (Rinne and Turner 1991, Pister 1998). This project addresses the need for more thorough pre-treatment surveys to provide baselines for judging the relative success of a future restoration. Results of this study confirm that the reaches surveyed provided good habitat for salmonids. Population numbers, densities, and biomass estimates of the non-native trout present in the study sections provided encouraging evidence for the ability of this system to support a restored westslope cutthroat trout population. A critical step for any fisheries management action is a period of evaluation to determine the success of the effort, or to learn from our mistakes. The data collected in this study will facilitate the meaningful comparisons between the restored westslope cutthroat trout and the present non-native trout community required for an accurate and thorough evaluation of the restoration effort.

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APPENDICES

APPENDIX A

HABITAT INVENTORY REPORTS

FB_HPRNT R1/R4 FISH HABITAT INVENTORY SYSTEM Run Date: 04/24/2001
v99.02c Header file Information Page: 1

Stream & Study: CHERRY CR AG1290000 I98

Tributary of: MADISON R
Survey Reach No.: 4
Reach Type: C
Forest: 11 - GALLATIN NF
District: 06 - BOZEMAN RD
Admin. Forest: 11 - GALLATIN NF
Admin. District: 06 - BOZEMAN RD
Ecoregion - Bailey: M332
Ecoregion - Omernik: 17
Gross Geology: VOLCANIC
Sub Geology: BASALT/ANDE
Township, Range, Sec: T03E,R02E ,S35
Base Quad Map Name: CHERRY CR. CANYON
Survey Reach Long:
Survey Reach Lat:
EPA Reach No.: 1002000712900.00
Lower EPA Boundary: MOUTH
Upper EPA Boundary: CHERRY CR, E FK
First Date of Survey: 07/27/1998
Unit (Metric/English: M

Habitat Observer: S.MORAN,K.DUFFY
Habitat Recorder: S.MORAN
Diver 1:
Diver 2:
Map Gradient: 1.1
Field Gradient: 1.0
Flow: 2.67
Elevation: 1661
Confinement: U
Cover Group: WOODED
Weather: PT CLOUDY
Non FS Inclusions: Y
Other Owners: TURNER ENTERPRISES
Wilderness (Y/N): N

Lower Boundary: MOUTH OF LFT BNK, SPRING-FED, 2ND ORDER TRIB
Upper Boundary: DIVERSON DAM AT DOWNSTREAM END OF COWBOY CANYON
Channel Type:
Comments: FOR ALL OF THIS INVENTORY DESCRIPTIONS BASED ON LOOKING UPSTREAM. ON INDIVIDUAL HABITAT SCREENS PHYSICAL VARIABLE 1 IS OCULARLY ESTIMATED LFT BNK STABILITY AND UNDERCUT AND RHT BNK DATA RESPECTIVELY. HIGH #S OF LWD ROOT WADS REFLECTS INCLUSION OF WILLOW ROOT WADS WHICH WERE A MAJOR HABITAT FEATURE PARTICULARLY IN THE BUTLER REACH. Start of reach trib. supplies most (~66%) of the flow in the beaver slough when it enters the slough 34.5 M upstream of the slough's confluence with Cherry Cr. Slough 1.2 M wide, .07 ave. depth, with sand substrate and sedge/ willow riparian veg. Reach 4 begins ~1/3 mi. upstream from the upstream end of Cherry Cr. Canyon. No fish were seen in the slough. Spring/beaver slough continues in a much deminished form for ~2/3 of a mi. up the left edge of the valley floor before petering out just upstream from road x-ing. Slough very turbid and stagnant, no fish were sighted.

FB_HPRNT R1/R4 FISH HABITAT INVENTORY SYSTEM Run Date: 04/24/2001
v99.02c Header file Information Page: 2

Stream & Study: CHERRY CR AG1290000 I98

Tributary of: MADISON R
Survey Reach No.: 5
Reach Type: C
Forest: 11 - GALLATIN NF
District: 06 - BOZEMAN RD
Admin. Forest: 11 - GALLATIN NF
Admin. District: 06 - BOZEMAN RD
Ecoregion - Bailey: M332
Ecoregion - Omernik: 17
Gross Geology: METAMORPHIC
Sub Geology: COARSE
Township, Range, Sec: T03S,R02E ,S26
Base Quad Map Name: CHERRY CR. CANYON
Survey Reach Long:
Survey Reach Lat:
EPA Reach No.: 1002000712900.00
Lower EPA Boundary: MOUTH
Upper EPA Boundary: CHERRY CR, E FK
First Date of Survey: 07/29/1998
Unit (Metric/English: M

Habitat Observer: S.MORAN,K.DUFFY
Habitat Recorder: S.MORAN
Diver 1:
Diver 2:
Map Gradient: 0.9
Field Gradient: 1.2
Flow: 0.80
Elevation: 1674
Confinement: U
Cover Group: WOODED
Weather: PT CLOUDY
Non FS Inclusions: Y
Other Owners: TURNER ENTERPRISES
Wilderness (Y/N): N

Lower Boundary: DIVERSION DAM AT MOUTH OF COWBOY CANYON
Upper Boundary: MOUTH OF E. FK. CHERRY CR.
Channel Type:
Comments:

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FB_HPRNT                 R1/R4 FISH HABITAT INVENTORY SYSTEM  Run Date: 04/24/2001
v99.02c                        Header file Information                 Page:   1

Stream & Study: CHERRY CR                             AG1300000 I98

         Tributary of: MADISON R
     Survey Reach No.:    6
           Reach Type: C                         Habitat Observer: S.MORAN,K.DUFFY
               Forest: 11 - GALLATIN NF          Habitat Recorder: S.MORAN
             District: 06 - BOZEMAN RD                    Diver 1:
        Admin. Forest: 11 - GALLATIN NF                   Diver 2:
      Admin. District: 06 - BOZEMAN RD               Map Gradient:  1.7
   Ecoregion - Bailey: M332                        Field Gradient:  1.5
  Ecoregion - Omernik: 17                                    Flow:   0.89
        Gross Geology: SEDIMENTARY                      Elevation:  1700
          Sub Geology: COARSE                         Confinement: U
Township, Range, Sec: T03S,R02E ,S35                  Cover Group: WOODED
  Base Quad Map Name: CHERRY CR. CANYON                   Weather: CLEAR
    Survey Reach Long:                              Non FS Inclusions: Y
     Survey Reach Lat:                                Other Owners: TURNER ENTERPRISES
        EPA Reach No.: 1002000713000.00             Wilderness (Y/N): N
   Lower EPA Boundary: CHERRY CR, E FK
   Upper EPA Boundary: HEADWATERS
First Date of Survey: 07/29/1998
Unit (Metric/English: M
       Lower Boundary: MOUTH OF E. FK. CHERRY CR.
       Upper Boundary: MOUTH OF CARPENTER CR.
         Channel Type:
Comments:
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         Tributary of: MADISON R
     Survey Reach No.:    7
           Reach Type: C                         Habitat Observer: S.MORAN
               Forest: 11 - GALLATIN NF          Habitat Recorder: S.MORAN
             District: 06 - BOZEMAN RD                    Diver 1:
        Admin. Forest: 11 - GALLATIN NF                   Diver 2:
      Admin. District: 06 - BOZEMAN RD               Map Gradient:  2.5
   Ecoregion - Bailey: M332                        Field Gradient:  2.0
  Ecoregion - Omernik: 17                                    Flow:   0.68
        Gross Geology: METAMORPHIC                      Elevation:  1752
          Sub Geology: QUARTZITE                      Confinement: M
Township, Range, Sec: T04S,R02E ,S11                  Cover Group: WOODED
  Base Quad Map Name: WILLOW SWAMP                        Weather: CLEAR
    Survey Reach Long:                              Non FS Inclusions: Y
     Survey Reach Lat:                                Other Owners: TURNER ENTERPRISES
        EPA Reach No.: 1002000713000.00             Wilderness (Y/N): N
   Lower EPA Boundary: CHERRY CR, E FK
   Upper EPA Boundary: HEADWATERS
First Date of Survey: 08/05/1998
Unit (Metric/English: M
       Lower Boundary: MOUTH OF CARPENTER CR.
       Upper Boundary: MOUTH OF SWEDEN CR.
         Channel Type:
Comments:
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FB_P02 v99.02c

Stream ID: AG1290000
EPA Reach: 1002000712900.00
Stream Name: CHERRY CR

R1/R4 FISH HABITAT INVENTORY SYSTEM
Summary of Main Channel Habitat Parameters
Listing by Survey Reach and by Habitat Type

Run date: 04/24/2001
Page 1

Forest: GALLATIN NF   District: BOZEMAN RD   Study: I98

Habitat Type	Total Number of Units	Number of Pocket Pools Total(n)	Number of Pocket Pools Mean(n)	Number of Pocket Pools per 100 m(n)	Pkt Pool Mean Depth (m)(n)	Total Pools in STPs(n)	Average Max Depth STP Cmplx(n)	Mean Crest Depth (m)(n)	Mean Resid. Max Depth (m)(n)	Residual Volume (m³) Total(n)	Residual Volume (m³) Mean(n)	LWD Total(n)	LWD n/100m(n)
Survey Reach: 4 Reach Type: C		Survey Reach Lower Boundary: MOUTH OF LFT BNK, SPRING-FED, 2ND ORDER TRIB Survey Reach Upper Boundary: DIVERSON DAM AT DOWNSTREAM END OF COWBOY CANYON											
LGR	26	123(26)	4.7(26)	12.3(26)	0.32(26)	-	-	-	-	-	-	55(26)	5.5(26)
RUN	16	74(16)	4.6(16)	12.4(16)	0.44(16)	-	-	-	-	-	-	34(16)	5.7(16)
SLB	2	-	-	-	-	-	-	0.43(2)	0.78(2)	176.7(2)	88.4(2)	2(2)	6.6(2)
SLM	26	-	-	-	-	-	-	0.36(26)	0.71(26)	3,248.7(26)	124.9(26)	43(26)	7.3(26)
SLR	4	-	-	-	-	-	-	0.49(4)	0.58(4)	355.0(4)	88.8(4)	8(4)	9.6(4)
SMB	3	-	-	-	-	-	-	0.41(3)	0.63(3)	209.7(3)	69.9(3)	3(3)	7.2(3)
SPA	1	-	-	-	-	-	-	0.32(1)	0.58(1)	112.5(1)	112.5(1)	0(1)	0.0(1)
Subtotals	78	197(42)				-				4,102.6(36)		145(78)	
Means			4.7(42)	12.4(42)	0.37(42)		-	0.39(36)	0.69(36)		114.0(36)		6.2(78)
Survey Reach: 5 Reach Type: C		Survey Reach Lower Boundary: DIVERSION DAM AT MOUTH OF COWBOY CANYON Survey Reach Upper Boundary: MOUTH OF E. FK. CHERRY CR.											
DMA	1	-	-	-	-	-	-	0.15(1)	0.55(1)	100.6(1)	100.6(1)	0(1)	0.0(1)
LGR	43	362(43)	8.4(43)	23.7(43)	0.32(43)	-	-	-	-	-	-	102(43)	6.7(43)
RUN	23	124(23)	5.4(23)	17.8(23)	0.39(23)	-	-	-	-	-	-	47(23)	6.8(23)
SLB	11	-	-	-	-	-	-	0.33(11)	0.57(11)	721.1(11)	65.6(11)	15(11)	8.1(11)
SLM	6	-	-	-	-	-	-	0.34(6)	0.60(6)	336.9(6)	56.1(6)	9(6)	10.4(6)
SLR	1	-	-	-	-	-	-	0.26(1)	0.65(1)	132.5(1)	132.5(1)	3(1)	10.5(1)
SLW	5	-	-	-	-	-	-	0.31(5)	0.54(5)	176.0(5)	35.2(5)	8(5)	15.8(5)
SMB	8	-	-	-	-	-	-	0.34(8)	0.48(8)	463.0(8)	57.9(8)	13(8)	9.2(8)
SMC	1	-	-	-	-	-	-	0.35(1)	2.65(1)	424.4(1)	424.4(1)	0(1)	0.0(1)
SUW	1	-	-	-	-	-	-	0.22(1)	0.98(1)	122.4(1)	122.4(1)	2(1)	8.8(1)
Subtotals	100	486(66)				-				2,476.8(34)		199(100)	
Means			7.4(66)	21.9(66)	0.34(66)		-	0.32(34)	0.63(34)		72.8(34)		7.2(100)
Totals	178	683(108)				-				6,579.4(70)		344(178)	
Means			6.3(108)	17.9(108)	0.35(108)		-	0.35(70)	0.66(70)		94.0(70)		6.7(178)

FB_PO2 v99.02c

R1/R4 FISH HABITAT INVENTORY SYSTEM
Summary of Main Channel Habitat Parameters
Listing by Survey Reach and by Habitat Type

Run date: 04/24/2001
Page 1

Stream ID: AG1300000
EPA Reach: 1002000713000.00
Stream Name: CHERRY CR

Forest: GALLATIN NF

District: BOZEMAN RD

Study: I98

Habitat Type	Total Number of Units	Number of Pocket Pools Total(n)	Mean(n)	per 100 m(n)	Pkt Pool Mean Depth (m)(n)	Total Pools in STPs(n)	Average Max Depth STP Cmplx(n)	Mean Crest Depth (m)(n)	Mean Resid. Max Depth (m)(n)	Residual Volume (m³) Total(n)	Residual Volume (m³) Mean(n)	LWD Total(n)	LWD n/100m(n)
Survey Reach: 6 Reach Type: C		Survey Reach Lower Boundary: MOUTH OF E. FK. CHERRY CR. Survey Reach Upper Boundary: MOUTH OF CARPENTER CR.											
GLD	2	8(2)	4.0(2)	12.1(2)	0.49(2)	-	-	-	-	-	-	6(2)	9.1(2)
LGR	61	428(61)	7.0(61)	17.6(61)	0.33(60)	-	-	-	-	-	-	190(61)	7.8(61)
RUN	32	134(32)	4.2(32)	18.3(32)	0.43(32)	-	-	-	-	-	-	69(32)	9.4(32)
SLB	3	-	-	-	-	-	-	0.33(3)	0.51(3)	147.7(3)	49.2(3)	4(3)	8.4(3)
SLM	44	-	-	-	-	-	-	0.30(44)	0.61(44)	2,978.4(44)	67.7(44)	86(44)	11.8(44)
SLW	9	-	-	-	-	-	-	0.29(9)	0.71(9)	772.5(9)	85.8(9)	19(9)	12.7(9)
SMB	1	-	-	-	-	-	-	0.33(1)	0.83(1)	57.6(1)	57.6(1)	2(1)	21.1(1)
SMW	2	-	-	-	-	-	-	0.20(2)	0.73(2)	111.0(2)	55.5(2)	4(2)	15.9(2)
SPW	1	-	-	-	-	-	-	0.14(1)	1.81(1)	125.4(1)	125.4(1)	2(1)	22.2(1)
SUW	2	-	-	-	-	-	-	0.26(2)	0.78(2)	70.7(2)	35.3(2)	2(2)	11.3(2)
Subtotals	157	570(95)								4,263.2(62)		384(157)	
Means			6.0(95)	17.7(95)	0.36(94)		-	0.29(62)	0.65(62)		68.8(62)		9.1(157)
Survey Reach: 7 Reach Type: C		Survey Reach Lower Boundary: MOUTH OF CARPENTER CR. Survey Reach Upper Boundary: MOUTH OF SWEDEN CR.											
DMV	2	-	-	-	-	-	-	0.13(2)	1.43(2)	765.3(2)	382.7(2)	20(2)	30.3(2)
DMW	1	-	-	-	-	-	-	0.26(1)	0.65(1)	86.2(1)	86.2(1)	3(1)	15.4(1)
GLD	1	2(1)	2.0(1)	15.6(1)	0.35(1)	-	-	-	-	-	-	1(1)	7.8(1)
HGR	4	68(4)	17.0(4)	33.4(4)	0.35(4)	-	-	-	-	-	-	12(4)	5.9(4)
LGR	37	521(37)	14.1(37)	18.6(37)	0.31(37)	-	-	-	-	-	-	162(37)	5.8(37)
RUN	12	48(12)	4.0(12)	19.4(12)	0.43(12)	-	-	-	-	-	-	37(12)	15.0(12)
SLB	3	-	-	-	-	-	-	0.23(3)	0.38(3)	50.7(3)	16.9(3)	2(3)	7.7(3)
SLM	17	-	-	-	-	-	-	0.24(17)	0.58(17)	753.2(17)	44.3(17)	27(17)	12.4(17)
SLW	3	-	-	-	-	-	-	0.24(3)	0.58(3)	92.9(3)	31.0(3)	4(3)	12.3(3)
SMB	3	-	-	-	-	-	-	0.32(3)	0.65(3)	120.8(3)	40.3(3)	2(3)	6.1(3)
SMO	1	-	-	-	-	-	-	0.28(1)	0.48(1)	36.0(1)	36.0(1)	0(1)	0.0(1)
SPA	1	-	-	-	-	-	-	0.14(1)	0.35(1)	12.5(1)	12.5(1)	2(1)	28.6(1)
SPW	3	-	-	-	-	-	-	0.20(3)	0.86(3)	119.5(3)	39.8(3)	4(3)	21.3(3)
SUW	2	-	-	-	-	-	-	0.26(2)	0.73(2)	69.7(2)	34.8(2)	3(2)	18.4(2)
Subtotals	90	639(54)				-				2,106.9(36)		279(90)	
Means			11.8(54)	19.6(54)	0.32(54)		-	0.24(36)	0.64(36)		58.5(36)		7.5(90)
Totals	247	1,209(149)				-				6,370.1(98)		663(247)	
Means			8.1(149)	18.6(149)	0.34(148)		-	0.27(98)	0.65(98)		65.0(98)		8.4(247)

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R1/R4 FISH HABITAT INVENTORY SYSTEM
Summary of Main Channel Physical Habitat Dimensions
Listing by Survey Reach and by Habitat Type

Run date: 04/24/2001
Page 1

Stream ID: AG1290000
EPA Reach: 1002000712900.00
Stream Name: CHERRY CR

Forest: GALLATIN NF District: BOZEMAN RD Study: I98

Habitat Type	Total Number of Units	Habitat Length (m) Total(n)	Habitat Length (m) Mean(n)	Habitat Length (m) Percent(n)	Mean Width (m)(n)	Habitat Depth (m) Mean(n)	Habitat Depth (m) Mean-Max(n)	Mean Width/Depth(n)	Habitat Area (m²) Total(n)	Habitat Area (m²) Mean(n)	Habitat Area (m²) Percent(n)	Habitat Volume (m³) Total(n)	Habitat Volume (m³) Mean(n)	Habitat Volume (m³) Percent(n)
Survey Reach: 4 Reach Type: C		Survey Reach Lower Boundary: MOUTH OF LFT BNK, SPRING-FED, 2ND ORDER TRIB; Survey Reach Upper Boundary: DIVERSON DAM AT DOWNSTREAM END OF COWBOY CANYON												
LGR	26	1,000.2(26)	38.5(26)	42.4(26)	8.4(26)	0.24(26)	-	37.46(26)	8,449.5(26)	325.0(26)	45.4(26)	1,997.0(26)	76.8(26)	33.5(26)
RUN	16	594.6(16)	37.2(16)	25.2(16)	7.2(16)	0.33(16)	-	22.35(16)	4,289.3(16)	268.1(16)	23.0(16)	1,414.4(16)	88.4(16)	23.8(16)
SLB	2	30.1(2)	15.1(2)	1.3(2)	7.5(2)	0.40(2)	1.21(2)	18.77(2)	225.4(2)	112.7(2)	1.2(2)	90.5(2)	45.2(2)	1.5(2)
SLM	26	591.9(26)	22.8(26)	25.1(26)	7.6(26)	0.44(26)	1.07(26)	17.93(26)	4,515.0(26)	173.7(26)	24.2(26)	1,976.5(26)	76.0(26)	33.2(26)
SLR	4	83.1(4)	20.8(4)	3.5(4)	7.3(4)	0.40(4)	1.07(4)	19.39(4)	608.6(4)	152.2(4)	3.3(4)	246.1(4)	61.5(4)	4.1(4)
SMB	3	41.8(3)	13.9(3)	1.8(3)	8.2(3)	0.44(3)	1.04(3)	18.64(3)	343.8(3)	114.6(3)	1.8(3)	152.4(3)	50.8(3)	2.6(3)
SPA	1	15.9(1)	15.9(1)	0.7(1)	12.2(1)	0.40(1)	0.90(1)	30.50(1)	194.0(1)	194.0(1)	1.0(1)	77.6(1)	77.6(1)	1.3(1)
Subtotals	78	2,357.6(78)		46.0(78)					18,625.6(78)		48.5(78)	5,954.5(78)		54.8(78)
Means			30.2(78)		7.9(78)	0.32(78)	1.07(36)	27.49(78)		238.8(78)			76.3(78)	
Survey Reach: 5 Reach Type: C		Survey Reach Lower Boundary: DIVERSION DAM AT MOUTH OF COWBOY CANYON; Survey Reach Upper Boundary: MOUTH OF E. FK. CHERRY CR.												
DMA	1	15.9(1)	15.9(1)	0.6(1)	11.5(1)	0.34(1)	0.70(1)	33.82(1)	182.9(1)	182.9(1)	0.9(1)	62.2(1)	62.2(1)	1.3(1)
LGR	43	1,525.0(43)	35.5(43)	55.1(43)	7.0(43)	0.20(43)	-	37.16(43)	10,701.1(43)	248.9(43)	54.1(43)	2,162.9(43)	50.3(43)	44.0(43)
RUN	23	695.6(23)	30.2(23)	25.1(23)	7.8(23)	0.25(23)	-	32.52(23)	5,401.1(23)	234.8(23)	27.3(23)	1,333.8(23)	58.0(23)	27.1(23)
SLB	11	184.5(11)	16.8(11)	6.7(11)	6.5(11)	0.39(11)	0.90(11)	17.29(11)	1,200.1(11)	109.1(11)	6.1(11)	467.0(11)	42.5(11)	9.5(11)
SLM	6	86.2(6)	14.4(6)	3.1(6)	6.7(6)	0.37(6)	0.93(6)	18.94(6)	576.1(6)	96.0(6)	2.9(6)	211.8(6)	35.3(6)	4.3(6)
SLR	1	28.7(1)	28.7(1)	1.0(1)	7.1(1)	0.41(1)	0.91(1)	17.32(1)	203.8(1)	203.8(1)	1.0(1)	83.6(1)	83.6(1)	1.7(1)
SLW	5	50.6(5)	10.1(5)	1.8(5)	6.0(5)	0.35(5)	0.85(5)	17.76(5)	304.0(5)	60.8(5)	1.5(5)	105.3(5)	21.1(5)	2.1(5)
SMB	8	140.6(8)	17.6(8)	5.1(8)	6.7(8)	0.34(8)	0.82(8)	19.91(8)	940.6(8)	117.6(8)	4.8(8)	322.6(8)	40.3(8)	6.6(8)
SMC	1	17.6(1)	17.6(1)	0.6(1)	9.1(1)	0.77(1)	3.00(1)	11.82(1)	160.2(1)	160.2(1)	0.8(1)	123.3(1)	123.3(1)	2.5(1)
SUW	1	22.7(1)	22.7(1)	0.8(1)	5.5(1)	0.36(1)	1.20(1)	15.28(1)	124.9(1)	124.9(1)	0.6(1)	45.0(1)	45.0(1)	0.9(1)
Subtotals	100	2,767.4(100)		54.0(100)					19,794.7(100)		51.5(100)	4,917.3(100)		45.2(100)
Means			27.7(100)		7.2(100)	0.25(100)	0.95(34)	32.31(100)		197.9(100)			49.2(100)	
Totals	178	5,125.0(178)		100.0(178)					38,420.3(178)		100.0(178)	10,871.7(178)		100.0(178)
Means			28.8(178)		7.5(178)	0.28(178)	1.01(70)	30.09(178)		215.8(178)			61.1(178)	

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R1/R4 FISH HABITAT INVENTORY SYSTEM
Summary of Main Channel Physical Habitat Dimensions
Listing by Survey Reach and by Habitat Type

Run date: 04/24/2001
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Stream ID: AG1300000
EPA Reach: 1002000713000.00
Stream Name: CHERRY CR

Forest: GALLATIN NF

District: BOZEMAN RD

Study: I98

Habitat Type	Total Number of Units	Habitat Length (m) Total(n)	Habitat Length (m) Mean(n)	Habitat Length (m) Percent(n)	Mean Width (m)(n)	Habitat Depth (m) Mean(n)	Habitat Depth (m) Mean-Max(n)	Mean Width/ Depth(n)	Habitat Area (m²) Total(n)	Habitat Area (m²) Mean(n)	Habitat Area (m²) Percent(n)	Habitat Volume (m³) Total(n)	Habitat Volume (m³) Mean(n)	Habitat Volume (m³) Percent(n)
Survey Reach: 6 Reach Type: C		Survey Reach Lower Boundary: MOUTH OF E. FK. CHERRY CR. Survey Reach Upper Boundary: MOUTH OF CARPENTER CR.												
GLD	2	66.1(2)	33.1(2)	1.6(2)	7.7(2)	0.21(2)	-	36.75(2)	510.1(2)	255.1(2)	1.8(2)	107.1(2)	53.6(2)	1.4(2)
LGR	61	2,426.0(61)	39.8(61)	57.6(61)	7.1(61)	0.21(61)	-	35.45(61)	17,258.8(61)	282.9(61)	60.3(61)	3,627.4(61)	59.5(61)	48.9(61)
RUN	32	730.3(32)	22.8(32)	17.4(32)	6.0(32)	0.29(32)	-	21.66(32)	4,413.0(32)	137.9(32)	15.4(32)	1,293.4(32)	40.4(32)	17.4(32)
SLB	3	47.6(3)	15.9(3)	1.1(3)	6.6(3)	0.37(3)	0.84(3)	18.34(3)	314.1(3)	104.7(3)	1.1(3)	115.3(3)	38.4(3)	1.6(3)
SLM	44	727.8(44)	16.5(44)	17.3(44)	6.4(44)	0.37(44)	0.91(44)	17.79(44)	4,644.7(44)	105.6(44)	16.2(44)	1,733.3(44)	39.4(44)	23.4(44)
SLW	9	149.6(9)	16.6(9)	3.6(9)	7.1(9)	0.38(9)	1.00(9)	19.17(9)	1,067.4(9)	118.6(9)	3.7(9)	400.7(9)	44.5(9)	5.4(9)
SMB	1	9.5(1)	9.5(1)	0.2(1)	7.3(1)	0.42(1)	1.16(1)	17.38(1)	69.3(1)	69.3(1)	0.2(1)	29.1(1)	29.1(1)	0.4(1)
SMW	2	25.1(2)	12.6(2)	0.6(2)	6.5(2)	0.33(2)	0.93(2)	19.79(2)	164.2(2)	82.1(2)	0.6(2)	54.4(2)	27.2(2)	0.7(2)
SPW	1	9.0(1)	9.0(1)	0.2(1)	7.7(1)	0.52(1)	1.95(1)	14.81(1)	69.3(1)	69.3(1)	0.2(1)	36.0(1)	36.0(1)	0.5(1)
SUW	2	17.7(2)	8.9(2)	0.4(2)	5.1(2)	0.28(2)	1.04(2)	18.17(2)	90.0(2)	45.0(2)	0.3(2)	25.6(2)	12.8(2)	0.3(2)
Subtotals	157	4,208.7(157)		53.1(157)					28,601.0(157)		55.3(157)	7,422.4(157)		61.9(157)
Means			26.8(157)		6.8(157)	0.26(157)	0.94(62)	29.00(157)		182.2(157)			47.3(157)	
Survey Reach: 7 Reach Type: C		Survey Reach Lower Boundary: MOUTH OF CARPENTER CR. Survey Reach Upper Boundary: MOUTH OF SWEDEN CR.												
DMV	2	66.1(2)	33.1(2)	1.8(2)	8.1(2)	0.44(2)	1.55(2)	18.59(2)	537.3(2)	268.7(2)	2.3(2)	237.0(2)	118.5(2)	5.2(2)
DMW	1	19.5(1)	19.5(1)	0.5(1)	6.8(1)	0.40(1)	0.91(1)	17.00(1)	132.6(1)	132.6(1)	0.6(1)	53.0(1)	53.0(1)	1.2(1)
GLD	1	12.8(1)	12.8(1)	0.3(1)	6.6(1)	0.22(1)	-	30.00(1)	84.5(1)	84.5(1)	0.4(1)	18.6(1)	18.6(1)	0.4(1)
HGR	4	203.7(4)	50.9(4)	5.5(4)	7.6(4)	0.20(4)	-	38.94(4)	1,546.1(4)	386.5(4)	6.7(4)	306.6(4)	76.6(4)	6.7(4)
LGR	37	2,799.4(37)	75.7(37)	75.4(37)	6.3(37)	0.17(37)	-	37.25(37)	17,585.0(37)	475.3(37)	76.0(37)	3,018.1(37)	81.6(37)	66.1(37)
RUN	12	247.0(12)	20.6(12)	6.7(12)	4.9(12)	0.24(12)	-	20.97(12)	1,222.6(12)	101.9(12)	5.3(12)	296.5(12)	24.7(12)	6.5(12)
SLB	3	25.9(3)	8.6(3)	0.7(3)	5.3(3)	0.23(3)	0.61(3)	23.56(3)	137.4(3)	45.8(3)	0.6(3)	31.0(3)	10.3(3)	0.7(3)
SLM	17	218.5(17)	12.9(17)	5.9(17)	5.6(17)	0.31(17)	0.83(17)	19.17(17)	1,219.9(17)	71.8(17)	5.3(17)	376.3(17)	22.1(17)	8.2(17)
SLW	3	32.5(3)	10.8(3)	0.9(3)	4.9(3)	0.30(3)	0.82(3)	16.84(3)	160.6(3)	53.5(3)	0.7(3)	47.5(3)	15.8(3)	1.0(3)
SMB	3	32.8(3)	10.9(3)	0.9(3)	5.6(3)	0.41(3)	0.97(3)	14.92(3)	184.7(3)	61.6(3)	0.8(3)	75.7(3)	25.2(3)	1.7(3)
SMO	1	12.1(1)	12.1(1)	0.3(1)	6.2(1)	0.26(1)	0.76(1)	23.85(1)	75.0(1)	75.0(1)	0.3(1)	19.5(1)	19.5(1)	0.4(1)
SPA	1	7.0(1)	7.0(1)	0.2(1)	5.1(1)	0.16(1)	0.49(1)	31.88(1)	35.7(1)	35.7(1)	0.2(1)	5.7(1)	5.7(1)	0.1(1)
SPW	3	18.8(3)	6.3(3)	0.5(3)	7.4(3)	0.37(3)	1.06(3)	22.14(3)	138.7(3)	46.2(3)	0.6(3)	50.9(3)	17.0(3)	1.1(3)
SUW	2	16.3(2)	8.2(2)	0.4(2)	5.6(2)	0.35(2)	0.99(2)	16.31(2)	91.2(2)	45.6(2)	0.4(2)	31.8(2)	15.9(2)	0.7(2)
Subtotals	90	3,712.4(90)		46.9(90)					23,151.4(90)		44.7(90)	4,568.2(90)		38.1(90)
Means			41.2(90)		6.2(90)	0.20(90)	0.88(36)	34.04(90)		257.2(90)			50.8(90)	
Totals	247	7,921.1(247)		100.0(247)					51,752.4(247)		100.0(247)	11,990.6(247)		100.0(247)
Means			32.1(247)		6.5(247)	0.23(247)	0.92(98)	31.36(247)		209.5(247)			48.5(247)	

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R1/R4 FISH HABITAT INVENTORY SYSTEM
Summary of Main Channel Physical Habitat Dimensions
Listing by Survey Reach and by Habitat Class

Run date: 04/24/2001
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Stream ID: AG1290000
EPA Reach: 1002000712900.00
Stream Name: CHERRY CR

Forest: GALLATIN NF District: BOZEMAN RD Study: I98

Habitat Class	Total Number of Units	Habitat Length (m) Total(n)	Habitat Length (m) Mean(n)	Habitat Length (m) Percent(n)	Mean Width (m)(n)	Habitat Depth (m) Mean(n)	Habitat Depth (m) Mean-Max(n)	Mean Width/Depth(n)	Habitat Area (m²) Total(n)	Habitat Area (m²) Mean(n)	Habitat Area (m²) Percent(n)	Habitat Volume (m«) Total(n)	Habitat Volume (m«) Mean(n)	Habitat Volume (m«) Percent(n)
Survey Reach: 4 Reach Type: C		Survey Reach Lower Boundary: MOUTH OF LFT BNK, SPRING-FED, 2ND-ORDER TRIB Survey Reach Upper Boundary: DIVERSON DAM AT DOWNSTREAM END OF COWBOY CANYON												
FAST	42	1,594.8(42)	38.0(42)	67.6(42)	8.0(42)	0.27(42)	-	31.82(42)	12,738.7(42)	303.3(42)	68.4(42)	3,411.4(42)	81.2(42)	57.3(42)
SLOW	36	762.8(36)	21.2(36)	32.4(36)	7.7(36)	0.43(36)	1.07(36)	18.42(36)	5,886.9(36)	163.5(36)	31.6(36)	2,543.1(36)	70.6(36)	42.7(36)
Subtotals	78	2,357.6(78)		46.0(78)					18,625.6(78)		48.5(78)	5,954.5(78)		54.8(78)
Means			30.2(78)		7.9(78)	0.32(78)	1.07(36)	27.49(78)		238.8(78)			76.3(78)	
Survey Reach: 5 Reach Type: C		Survey Reach Lower Boundary: DIVERSION DAM AT MOUTH OF COWBOY CANYON Survey Reach Upper Boundary: MOUTH OF E. FK. CHERRY CR.												
FAST	66	2,220.6(66)	33.6(66)	80.2(66)	7.3(66)	0.22(66)	-	35.71(66)	16,102.3(66)	244.0(66)	81.3(66)	3,496.7(66)	53.0(66)	71.1(66)
SLOW	34	546.8(34)	16.1(34)	19.8(34)	6.8(34)	0.38(34)	0.95(34)	18.49(34)	3,692.4(34)	108.6(34)	18.7(34)	1,420.6(34)	41.8(34)	28.9(34)
Subtotals	100	2,767.4(100)		54.0(100)					19,794.7(100)		51.5(100)	4,917.3(100)		45.2(100)
Means			27.7(100)		7.2(100)	0.25(100)	0.95(34)	32.31(100)		197.9(100)			49.2(100)	
Totals	178	5,125.0(178)		100.0(178)					38,420.3(178)		100.0(178)	10,871.7(178)		100.0(178)
Means			28.8(178)		7.5(178)	0.28(178)	1.01(70)	30.09(178)		215.8(178)			61.1(178)	

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R1/R4 FISH HABITAT INVENTORY SYSTEM
Summary of Main Channel Habitat Parameters
Listing by Survey Reach and by Habitat Class

Run date: 04/24/2001
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Stream ID: AG1290000
EPA Reach: 1002000712900.00
Stream Name: CHERRY CR

Forest: GALLATIN NF District: BOZEMAN RD Study: I98

Habitat Class	Total Number of Units	Number of Pocket Pools Total(n)	Number of Pocket Pools Mean(n)	Number of Pocket Pools per 100 m(n)	Pkt Pool Mean Depth (m)(n)	Total Pools in STPs(n)	Average Max Depth STP Cmplx(n)	Mean Crest Depth (m)(n)	Mean Resid. Max Depth (m)(n)	Residual Volume (m«) Total(n)	Residual Volume (m«) Mean(n)	LWD Total(n)	LWD n/100m(n)
Survey Reach: 4 Reach Type: C		Survey Reach Lower Boundary: MOUTH OF LFT BNK, SPRING-FED, 2ND ORDER TRIB Survey Reach Upper Boundary: DIVERSON DAM AT DOWNSTREAM END OF COWBOY CANYON											
FAST	42	197(42)	4.7(42)	12.4(42)	0.37(42)	-	-	-	-	-	-	89(42)	5.6(42)
SLOW	36	-	-	-	-	-	-	0.39(36)	0.69(36)	4,102.6(36)	114.0(36)	56(36)	7.3(36)
Subtotals	78	197(42)				-				4,102.6(36)		145(78)	
Means			4.7(42)	12.4(42)	0.37(42)		-	0.39(36)	0.69(36)		114.0(36)		6.2(78)
Survey Reach: 5 Reach Type: C		Survey Reach Lower Boundary: DIVERSION DAM AT MOUTH OF COWBOY CANYON Survey Reach Upper Boundary: MOUTH OF E. FK. CHERRY CR.											
FAST	66	486(66)	7.4(66)	21.9(66)	0.34(66)	-	-	-	-	-	-	149(66)	6.7(66)
SLOW	34	-	-	-	-	-	-	0.32(34)	0.63(34)	2,476.8(34)	72.8(34)	50(34)	9.1(34)
Subtotals	100	486(66)				-				2,476.8(34)		199(100)	
Means			7.4(66)	21.9(66)	0.34(66)		-	0.32(34)	0.63(34)		72.8(34)		7.2(100)
Totals	178	683(108)				-				6,579.4(70)		344(178)	
Means			6.3(108)	17.9(108)	0.35(108)		-	0.35(70)	0.66(70)		94.0(70)		6.7(178)

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R1/R4 FISH HABITAT INVENTORY SYSTEM
Summary of Main Channel Physical Habitat Dimensions
Listing by Survey Reach and by Habitat Class

Run date: 04/24/2001
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Stream ID: AG1300000
EPA Reach: 1002000713000.00
Stream Name: CHERRY CR

Forest: GALLATIN NF

District: BOZEMAN RD

Study: I98

Habitat Class	Total Number of Units	Habitat Length (m) Total(n)	Mean(n)	Percent(n)	Mean Width (m)(n)	Habitat Depth (m) Mean(n)	Mean-Max(n)	Mean Width/ Depth(n)	Habitat Area (m²) Total(n)	Mean(n)	Percent(n)	Habitat Volume (m³) Total(n)	Mean(n)	Percent(n)
Survey Reach: 6 Reach Type: C		Survey Reach Lower Boundary: MOUTH OF E. FK. CHERRY CR. Survey Reach Upper Boundary: MOUTH OF CARPENTER CR.												
FAST	95	3,222.4(95)	33.9(95)	76.6(95)	6.9(95)	0.23(95)	-	32.35(95)	22,181.9(95)	233.5(95)	77.6(95)	5,027.9(95)	52.9(95)	67.7(95)
SLOW	62	986.3(62)	15.9(62)	23.4(62)	6.5(62)	0.37(62)	0.94(62)	18.05(62)	6,419.1(62)	103.5(62)	22.4(62)	2,394.5(62)	38.6(62)	32.3(62)
Subtotals	157	4,208.7(157)		53.1(157)					28,601.0(157)		55.3(157)	7,422.4(157)		61.9(157)
Means			26.8(157)		6.8(157)	0.26(157)	0.94(62)	29.00(157)		182.2(157)			47.3(157)	
Survey Reach: 7 Reach Type: C		Survey Reach Lower Boundary: MOUTH OF CARPENTER CR. Survey Reach Upper Boundary: MOUTH OF SWEDEN CR.												
FAST	54	3,262.9(54)	60.4(54)	87.9(54)	6.3(54)	0.18(54)	-	36.10(54)	20,438.3(54)	378.5(54)	88.3(54)	3,639.8(54)	67.4(54)	79.7(54)
SLOW	36	449.5(36)	12.5(36)	12.1(36)	6.0(36)	0.34(36)	0.88(36)	19.11(36)	2,713.2(36)	75.4(36)	11.7(36)	928.5(36)	25.8(36)	20.3(36)
Subtotals	90	3,712.4(90)		46.9(90)					23,151.4(90)		44.7(90)	4,568.2(90)		38.1(90)
Means			41.2(90)		6.2(90)	0.20(90)	0.88(36)	34.04(90)		257.2(90)			50.8(90)	
Totals	247	7,921.1(247)		100.0(247)					51,752.4(247)		100.0(247)	11,990.6(247)		100.0(247)
Means			32.1(247)		6.5(247)	0.23(247)	0.92(98)	31.36(247)		209.5(247)			48.5(247)	

FB_P02 v99.02c

R1/R4 FISH HABITAT INVENTORY SYSTEM
Summary of Main Channel Habitat Parameters
Listing by Survey Reach and by Habitat Class

Run date: 04/24/2001
Page 1

Stream ID: AG1300000
EPA Reach: 1002000713000.00
Stream Name: CHERRY CR

Forest: GALLATIN NF

District: BOZEMAN RD

Study: I98

Habitat Class	Total Number of Units	Number of Pocket Pools Total(n)	Mean(n)	per 100 m(n)	Pkt Pool Mean Depth (m)(n)	Total Pools in STPs(n)	Average Max Depth STP Cmplx(n)	Mean Crest Depth (m)(n)	Mean Resid. Max Depth (m)(n)	Residual Volume (m³) Total(n)	Mean(n)	LWD Total(n)	n/100m(n)
Survey Reach: 6 Reach Type: C		Survey Reach Lower Boundary: MOUTH OF E. FK. CHERRY CR. Survey Reach Upper Boundary: MOUTH OF CARPENTER CR.											
FAST	95	570(95)	6.0(95)	17.7(95)	0.36(94)	-	-	-	-	-	-	265(95)	8.2(95)
SLOW	62	-	-	-	-	-	-	0.29(62)	0.65(62)	4,263.2(62)	68.8(62)	119(62)	12.1(62)
Subtotals	157	570(95)				-				4,263.2(62)		384(157)	
Means			6.0(95)	17.7(95)	0.36(94)		-	0.29(62)	0.65(62)		68.8(62)		9.1(157)
Survey Reach: 7 Reach Type: C		Survey Reach Lower Boundary: MOUTH OF CARPENTER CR. Survey Reach Upper Boundary: MOUTH OF SWEDEN CR.											
FAST	54	639(54)	11.8(54)	19.6(54)	0.32(54)	-	-	-	-	-	-	212(54)	6.5(54)
SLOW	36	-	-	-	-	-	-	0.24(36)	0.64(36)	2,106.9(36)	58.5(36)	67(36)	14.9(36)
Subtotals	90	639(54)				-				2,106.9(36)		279(90)	
Means			11.8(54)	19.6(54)	0.32(54)		-	0.24(36)	0.64(36)		58.5(36)		7.5(90)
Totals	247	1,209(149)				-				6,370.1(98)		663(247)	
Means			8.1(149)	18.6(149)	0.34(148)		-	0.27(98)	0.65(98)		65.0(98)		8.4(247)

FB_P05 v99.02c

R1/R4 FISH HABITAT INVENTORY SYSTEM
Summary of Main Channel Substrate Condition
Listing by Survey Reach and by Habitat Class

Run date: 04/24/2001
Page 1

Stream ID: AG1290000
EPA Reach: 1002000712900.00
Stream Name: CHERRY CR

Forest: GALLATIN NF   District: BOZEMAN RD   Study: I98

Habitat Class	Total Number of Units	Number of Meas. Units	Number of Est. Units	Fines	Small Gravel	Gravel	Small Cobble	Cobble	Small Boulder	Boulder	Bedrock	Mean % Surface Fines
				Mean Percent Substrate Coverage								
Survey Reach:4 Reach Type: C	Survey Reach Lower Boundary: MOUTH OF LFT BNK, SPRING-FED, 2ND ORDER TRIB; Survey Reach Upper Boundary: DIVERSON DAM AT DOWNSTREAM END OF COWBOY CANYON											
FAST	42	2	4	10.2	5.8	32.8	34.8	15.0	1.3	0.2	0.0	6.2
SLOW	36	2	4	18.2	8.2	34.3	24.7	9.5	0.2	0.0	5.0	8.3
Subtotals Means	78	4	8	14.2	7.0	33.6	29.8	12.3	0.8	0.1	2.5	7.4
Survey Reach:5 Reach Type: C	Survey Reach Lower Boundary: DIVERSION DAM AT MOUTH OF COWBOY CANYON; Survey Reach Upper Boundary: MOUTH OF E. FK. CHERRY CR.											
FAST	66	2	3	10.8	7.2	36.4	27.6	16.4	1.0	0.4	0.0	6.2
SLOW	34	2	3	15.0	10.4	45.4	20.4	8.4	0.4	0.0	0.0	8.1
Subtotals Means	100	4	6	12.9	8.8	40.9	24.0	12.4	0.7	0.2	0.0	7.0
Totals Means	178	8	14	13.6	7.8	36.9	27.1	12.3	0.7	0.1	1.4	7.2

FB_P05 v99.02c

R1/R4 FISH HABITAT INVENTORY SYSTEM
Summary of Main Channel Substrate Condition
Listing by Survey Reach and by Habitat Class

Run date: 04/24/2001
Page 1

Stream ID: AG1300000
EPA Reach: 1002000713000.00
Stream Name: CHERRY CR

Forest: GALLATIN NF   District: BOZEMAN RD   Study: I98

Habitat Class	Total Number of Units	Number of Meas. Units	Number of Est. Units	Fines	Small Gravel	Gravel	Small Cobble	Cobble	Small Boulder	Boulder	Bedrock	Mean % Surface Fines
				Mean Percent Substrate Coverage								
Survey Reach:6 Reach Type: C	Survey Reach Lower Boundary: MOUTH OF E. FK. CHERRY CR.; Survey Reach Upper Boundary: MOUTH OF CARPENTER CR.											
FAST	95	2	4	7.0	6.7	31.7	31.5	22.0	1.0	0.0	0.0	5.1
SLOW	62	2	4	10.3	10.5	45.0	24.3	9.8	0.2	0.0	0.0	7.0
Subtotals Means	157	4	8	8.7	8.6	38.3	27.9	15.9	0.6	0.0	0.0	6.1
Survey Reach:7 Reach Type: C	Survey Reach Lower Boundary: MOUTH OF CARPENTER CR.; Survey Reach Upper Boundary: MOUTH OF SWEDEN CR.											
FAST	54	-	2	3.0	3.0	39.0	37.5	14.5	3.0	0.0	0.0	3.2
SLOW	36	-	3	5.0	6.7	41.7	26.3	13.0	7.3	0.0	0.0	4.3
Subtotals Means	90	-	5	4.2	5.2	40.6	30.8	13.6	5.6	0.0	0.0	3.7
Totals Means	247	4	13	7.4	7.6	39.0	28.8	15.2	2.1	0.0	0.0	5.2

APPENDIX B

DENSITY AND BIOMASS ESTIMATES

		1998			
Section	Species	Mean weight age 1+ (g)	Biomass (g/m^2)	Biomass (kg/km)	Percent of Total
Butler	Brook	60.2	3.5	30.1	36.7
	Rainbow	123.8	5.9	51.9	63.3
	Combined		9.4	82.0	
Cowboy Canyon	Brook	56.3	6.1	43.3	66.5
	Rainbow	82.3	3.1	21.8	33.5
	Combined		9.2	65.1	
Cow Camp	Brook	40.5	6.5	46.3	92.9
	Rainbow	100.3	0.5	4.5	7.1
	Combined		7.0	50.8	

		1999			
Section	Species	Mean weight age 1+ (g)	Biomass (g/m^2)	Biomass (kg/km)	Percent of Total
Butler	Brook	87.7	6.3	55.1	41.5
	Rainbow	118.5	8.9	77.8	58.5
	Combined		15.2	132.9	
Cowboy Canyon	Brook	66.0	5.4	38.5	63.3
	Rainbow	89.1	3.2	22.3	36.7
	Combined		8.6	60.8	
Cow Camp	Brook	46.1	7.4	52.9	91.5
	Rainbow	73.4	0.7	4.9	8.5
	Combined		8.1	57.8	

		1998		1999	
Section	Species	Density (fish per m^2)	Percent	Density (fish per m^2)	Percent
Butler	Brook	0.057	54.3	0.072	48.9
	Rainbow	0.048	45.7	0.075	51.1
	Combined	0.105		0.147	
Cowboy Canyon	Brook	0.109	73.6	0.082	70.1
	Rainbow	0.037	26.4	0.035	29.9
	Combined	0.146		0.117	
Cow Camp	Brook	0.160	96.4	0.161	94.5
	Rainbow	0.006	3.6	0.009	5.5
	Combined	0.166		0.170	

APPENDIX C

OTOLITH READINGS

Butler	RBT		Age	
Fish #	Length (mm)	Length (inches)	Otolith	Scale
1	335	13.2	3	3
2	318	12.5	2	2
3	305	12.0	3	3
4	398	15.7	3	3
5	348	13.7	3	3
6	380	15.0	4	4

Canyon	RBT		Age	
Fish #	Length (mm)	Length (inches)	Otolith	Scale
1	233	9.2	3	2?
2	222	8.7	3	3?
3	209	8.2	2	2
4	280	11.0	2	no scales
5	292	11.5	2	3
6	279	11.0	3	3

Cow Camp	RBT		Age	
Fish #	Length (mm)	Length (inches)	Otolith	Scale
1	272	10.7	3	no scales
2	285	11.2	4	4
3	264	10.4	3	3
4	279	11.0	3	3
5	216	8.5	3	3
6	225	8.9	3	3

Butler	EBT		Age	
Fish #	Length (mm)	Length (inches)	Otolith	Scale
1	320	12.6	3	3
2	252	9.9	2	2
3	249	9.8	2	2
4	238	9.4	3	3
5	230	9.1	2	2
6	217	8.5	2	2

Canyon	**EBT**		Age	
Fish #	Length (mm)	Length (inches)	Otolith	Scale
1	266	10.5	3	2?
2	234	9.2	2	2
3	220	8.7	2	2
4	211	8.3	2	2
5	219	8.6	2	2
6	211	8.3	2	2

Cow Camp	**EBT**		Age	
Fish #	Length (mm)	Length (inches)	Otolith	Scale
1	235	9.3	2	2
2	245	9.7	3	3?
3	243	9.6	3	3
4	236	9.3	3	3
5	220	8.7	3	3
6	205	8.1	2	2

APPENDIX D

AGE-LENGTH KEYS

1998 Butler EBT Age-Length Key			Sample allocation per age-group			
Length group	No. in sample	No. (age) in Sub sample	Age 0	Age 1	Age 2	Age 3
1- 1.9	2	0	2			
2- 2.9	12	0	13*			
3- 3.9	30	0	30*			
4- 4.9	12	0	8*	4*		
5- 5.9	72	3 (1)		72		
6- 6.9	90	6 (1)		90		
7- 7.9	33	6 (1)		33		
8- 8.9	16	1 (1) 2 (2)		5	11	
9- 9.9	6	3 (2)			6	
10- 10.9	3	2 (2) 1 (3)	(* supported by length freq.)		2	1
		Total in:	**51**	**204**	**19**	**1**
		% in age:		**91**	**8.5**	**0.5**

1998 Canyon EBT Age-Length Key			Sample allocation per age-group			
Length group	No. in sample	No. (age) in Sub sample	Age 0	Age 1	Age 2	Age 3
2- 2.9	4	0	4*			
3- 3.9	10	0	10*			
4- 4.9	53	0	2*	51*		
5- 5.9	197	2 (1)		197		
6- 6.9	24	3 (1) 1 (2)		18	6	
7- 7.9	44	2 (2)			44	
8- 8.9	35	5 (2)			35	
9- 9.9	26	9 (3)				26
10- 10.9	8	5 (3)				8
11- 11.9	1	1 (3)	(* supported by length freq.)			1
		Total in:	**16**	**266**	**85**	**35**
		% in age:		**69**	**22**	**9**

1998 Cow Camp EBT Age-Length Key			Sample allocation per age-group				
Length group	No. in sample	No. (age) in Sub sample		Age 0	Age 1	Age 2	Age 3
1- 1.9	0	0		0			
2- 2.9	68	0		68*			
3- 3.9	130	0		130*			
4- 4.9	152	0			152*		
5- 5.9	131	1 (1)			131		
6- 6.9	67	3 (1)			67		
7- 7.9	47	2 (1) 6 (2)			16	31	
8- 8.9	20	3 (2) 2 (3)				12	8
9- 9.9	8	7 (3)					8
10- 10.9	1	1 (3)	(* supported by length freq.)				1
			Total in:	**198**	**266**	**43**	**17**
			% in age:		**82**	**13**	**5**

1998 Butler RBT Age-Length Key			Sample allocation per age-group					
Length group	No. in sample	No. (age) in Sub sample	Age 0	Age 1	Age 2	Age 3	Age 4	Age 4+
1- 1.9	0	0	0					
2- 2.9	0	0	0					
3- 3.9	1	0	0					
4- 4.9	20	0		21*				
5- 5.9	45	2 (1)		45				
6- 6.9	27	3 (1)		27				
7- 7.9	20	3 (1)		20				
8- 8.9	20	4 (1)		20				
9- 9.9	17	1(2) 1(3)			9	8		
10- 10.9	9	1 (2)			9			
11- 11.9	9	2 (2)			9			
12- 12.9	9	1(2) 1(3)			4	5		
13- 13.9	6	3 (3)				6		
14- 14.9	2	0					**2***	
15- 15.9	4	0	(*supported by length freq. or **otoliths**)				**4***	
16- 16.9	1	0						1*
		Total in:	**0**	**132**	**31**	**19**	**6**	**1**
		% in age:	**0**	**69.5**	**16**	**10**	**3**	**0.5**

1998 Canyon RBT Age-Length Key				Sample allocation per age-group			
Length group	No. in sample	No. (age) in Sub sample		Age 0	Age 1	Age 2	Age 3
1- 1.9	0	0		0			
2- 2.9	0	0		0			
3- 3.9	0	0		0			
4- 4.9	12	0			12 *		
5- 5.9	36	2 (1)			36		
6- 6.9	15	2 (1)			15		
7- 7.9	30	3 (1)			30		
8- 8.9	22	1 (1) 3 (2)			6	16	
9- 9.9	6	2 (2) 1 (3)				4	2
10- 10.9	10	3 (3)					10
11- 11.9	2	2 (3)					2
12- 12.9	2	0	(*supported by histogram and **otoliths**)				**2***
			Total in:	**0**	**99**	**20**	**16**
			% in age:	**0**	**73**	**15**	**12**

1998 Cow Camp RBT Age-Length Key				Sample allocation per age-group				
Length group	No. in sample	No. (age) in Sub sample		Age 0	Age 1	Age 2	Age 3	Age 4
1- 1.9	0	0		0				
2- 2.9	16	0		16*				
3- 3.9	0	0		0				
4- 4.9	0	0		0				
5- 5.9	0	0		0				
6- 6.9	2	1 (1)			2			
7- 7.9	8	6 (1)			8			
8- 8.9	5	1(1)3 (2)			1	4		
9- 9.9	1	1 (3)					1	
10- 10.9	2	2 (4)						2
			Total in:	**16**	**11**	**4**	**1**	**2**
			% in age:		**61**	**22**	**6**	**11**

1999 Butler EBT Age-Length Key			Sample allocation per age-group				
Length group	No. in sample	No. (age) in Sub sample		Age 0	Age 1	Age 2	Age 3
1- 1.9	0	0		0			
2- 2.9	4	0		4			
3- 3.9	39	0		39			
4- 4.9	10	0		10*			
5- 5.9	28	1 (1)			28		
6- 6.9	125	3 (1)			125		
7- 7.9	51	3 (1)			51		
8- 8.9	37	2 (1) 1 (2)			24	13	
9- 9.9	38	6 (2)				38	
10- 10.9	22	4 (2) 2 (3)				15	7
11- 11.9	3	0	*(supported by length freq. and **otoliths?**)				3*
			Total in:	**53**	**228**	**66**	**10**
			% in age:		**75**	**22**	**3**

1999 Canyon EBT Age-Length Key			Sample allocation per age-group					
Length group	No. in sample	No. (age) in Sub sample		Age 0	Age 1	Age 2	Age 3	Age 4
1- 1.9	0	0		0				
2- 2.9	43	0		44*				
3- 3.9	31	0		31*				
4- 4.9	48	0			48*			
5- 5.9	86	0			86*			
6- 6.9	30	2 (1)			30			
7- 7.9	66	1 (1) 4(2)			13	53		
8- 8.9	44	3 (2)				44		
9- 9.9	14	1(2) 2 (3)				5	9	
10- 10.9	5	2 (3)					5	
11- 11.9	4	1(3) 2 (4)	*(supported by length freq.)				1	3
			Total in:	**74**	**177**	**102**	**15**	**3**
			% in age:		**60**	**34**	**5**	**1**

1999 Cow Camp EBT Age-Length Key			Sample allocation per age-group			
Length group	No. in sample	No. (age) in Sub sample	Age 0	Age 1	Age 2	Age 3
2- 2.9	14	0	14*			
3- 3.9	6	0	6*			
4- 4.9	147	0		147*		
5- 5.9	111	1 (1)		111		
6- 6.9	96	1 (1) 1 (2)		48	48	
7- 7.9	56	1 (1) 3 (2)		14	42	
8- 8.9	31	4 (2) 2 (3)			21	10
9- 9.9	9	4 (3)				9
10- 10.9	1	1 (3)				1
11- 11.9	1	1 (3)	*(supported by length freq.)			1
		in age:	**20**	**320**	**111**	**21**
		% in age:		**71**	**25**	**4**

1999 Butler RBT Age-Length Key			Sample allocation per age-group				
Length group	No. in sample	No. (age) in sub sample	Age 0	Age 1	Age 2	Age 3	Age 4
2- 2.9	11	0	11*				
3- 3.9	4	0	4*				
4- 4.9	17	0		17*			
5- 5.9	64	1 (1)		64			
6- 6.9	66	3 (1)		66			
7- 7.9	42	1 (1)		42			
8- 8.9	33	2(1) 1(2)		22	11		
9- 9.9	38	4 (2)			38		
10- 10.9	28	3 (2)			28		
11- 11.9	14	1(2)1(3)			7	7	
12- 12.9	10	3 (3)				10	
13 –13.9	7	1(3)1(4)	*(supported by length freq.)			4	3
14- 14.9	8	2(3)1(4)				5	3
		Total in:	**15**	**211**	**84**	**26**	**6**
		% in age:		**65**	**25**	**8**	**2**

1999 Canyon RBT Age-Length Key			Sample allocation per age-group				
Length group	No. in sample	No. (age) in Sub sample		Age 0	Age 1	Age 2	Age 3
2- 2.9	9	0		9			
3- 3.9	0	0		0			
4- 4.9	5	0			5*		
5- 5.9	46	1 (1)			46		
6- 6.9	16	2 (1)			16		
7- 7.9	20	3 (1)			20		
8- 8.9	19	2 (2)				19	
9- 9.9	16	4 (2)				16	
10- 10.9	12	3 (2) 2 (3)				7	5
11- 11.9	4	1 (3)					4
12- 12.9	2	0					2*
			Total in:	**9**	**87**	**42**	**11**
			% in age:		**62**	**30**	**8**

1999 Cow Camp RBT Age-Length Key			Sample allocation per age-group				
Length group	No. in sample	No.(age) in sub sample		Age 0	Age 1	Age 2	Age 3
2- 2.9	4	0		4*			
3- 3.9	0	0		0			
4- 4.9	8	0			8*		
5- 5.9	6	3 (1)			6		
6- 6.9	1	1 (1)			1		
7- 7.9	3	2 (1)			3		
8- 8.9	4	3 (2)				4	
9- 9.9	3	3 (2)				3	
10- 10.9	2	2 (3)					2
			Total in:	**4**	**18**	**7**	**2**
			% in age:		**67**	**26**	**7**

APPENDIX E

BACK-CALCUATED MEAN LENGTHS-AT-AGE

Butler 1998 brook trout		Length at age (mm)			
Age group	Year class	1	2	3	n
1	99	136.4			12
2	98	155.5	205.8		7
3	97	148.5	192.3	229.8	1
	Mean	142.5	204.1	229.8	

Butler 1998 rainbow trout		Length at age (mm)			
Age group	Year class	1	2	3	n
1	99	117.1			14
2	98	121.5	197.0		5
3	97	131.4	204.7	273.3	5
	Mean	121.3	200.8	273.3	

Canyon 1998 brook trout		Length at age (mm)			
Age group	Year class	1	2	3	n
1	98	133.0			5
2	97	151.7	182.3		8
3	96	156.4	193.6	228.2	15
	Mean	150.9	189.7	228.2	

Canyon 1998 rainbow trout		Length at age (mm)			
Age group	Year class	1	2	3	n
1	98	109.1			8
2	97	85.8	162.8		5
3	96	107.4	170.3	231.1	6
	Mean	102.4	166.8	231.1	

Cow Camp 1998 brook trout		Length at age (mm)			
Age group	Year class	1	2	3	n
1	98	131.8			6
2	97	130.6	172.4		9
3	96	133.6	172.3	209.6	10
	Mean	132.1	172.4	209.6	

Cow Camp 1998 rainbow trout		Length at age (mm)				
Age group	Year class	1	2	3	4	n
1	98	167.2				8
2	97	162.5	189.1			3
3	96	176.6	205.6	229.3		1
4	95	158.8	204.5	234.0	258.3	2
	Mean	165.7	197.0	232.5	258.3	

Butler 1999 brook trout		Length at age (mm)			
Age group	Year class	1	2	3	n
1	99	142.7			10
2	98	159.4	212.8		11
3	97	145.4	192.5	245.4	2
	Mean	151.3	209.7	245.1	

Butler 1999 rainbow trout		Length at age (mm)				
Age group	Year Class	1	2	3	4	n
1	99	110.0				7
2	98	104.2	187.1			9
3	97	118.7	193.0	275.1		7
4	96	133.1	199.8	266.1	321.4	2
	Mean	111.7	190.8	273.1	321.4	

Cowboy Canyon 1999 brook trout		Length at age (mm)				
Age group	Year class	1	2	3	4	n
1	96	127.6				3
2	97	126.0	174.3			8
3	98	137.3	183.3	227.0		5
4	99	144.1	192.3	239.8	275.3	2
	Mean	131.4	179.7	230.7	275.3	

Canyon 1999 rainbow trout		Length at age (mm)			
Age group	Year class	1	2	3	n
1	99	103.7			6
2	98	143.3	207.1		9
3	97	110.0	190.0	248.9	3
	Mean	124.5	202.8	248.9	

Cow Camp 1999 brook trout		Length at age (mm)			
Age group	Year class	1	2	3	n
1	99	165.5			3
2	98	177.0	187.2		8
3	97	197.7	215.5	233.5	8
	Mean	183.9	201.3	233.5	

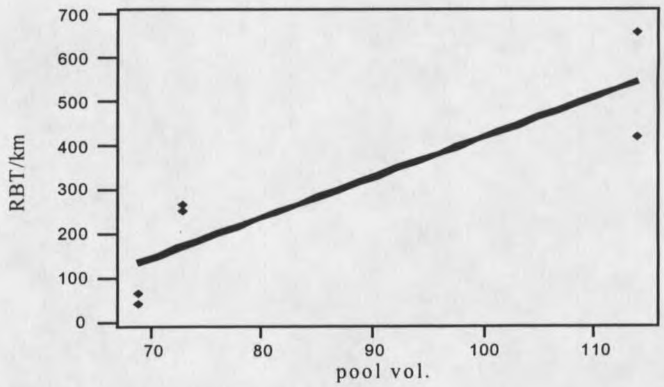
Cow Camp 1999 rainbow trout		Length at age (mm)			
Age group	Year class	1	2	3	n
1	99	108.0			6
2	98	127.4	184.9		6
3	97	146.1	178.4	229.7	2
	Mean	121.8	183.3	229.7	

APPENDIX F

SELECTED FISH/ HABITAT CORRELATIONS

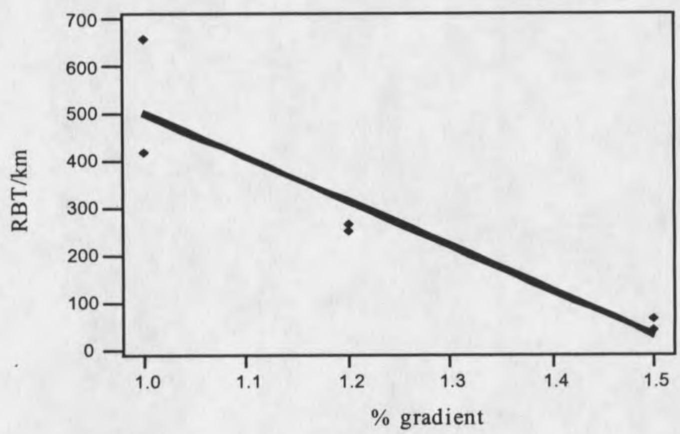
RBT numbers/km correlated with pool volume

R-Sq = 78.7 %



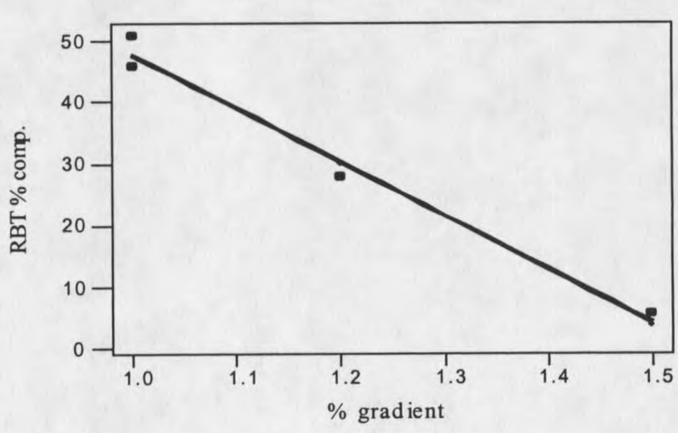
RBT numbers/km correlated with % gradient

R-Sq = 85.3 %



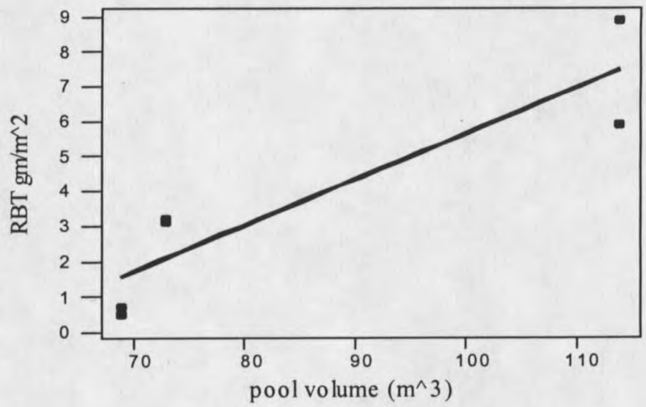
RBT % composition correlated with % gradient

R-Sq = 98.9 %



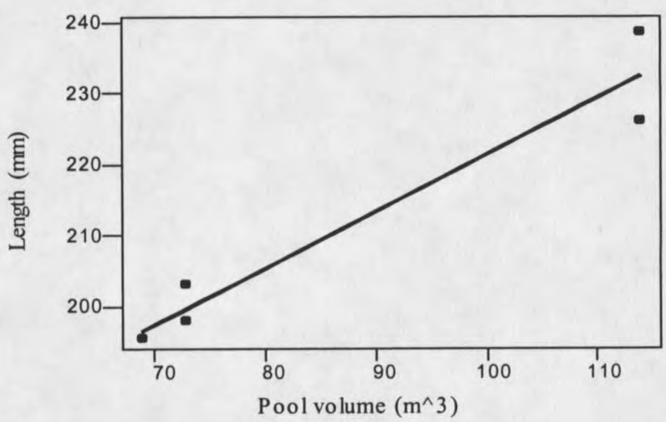
RBT biomass correlated with pool volume

R-Sq = 83.3 %



EBT Meann length-at-age 2 correlated with pool volume

R-Sq = 94.3 %



RBT B-C growth age 2 correlated with % gradient

R-Sq = 78.5 %